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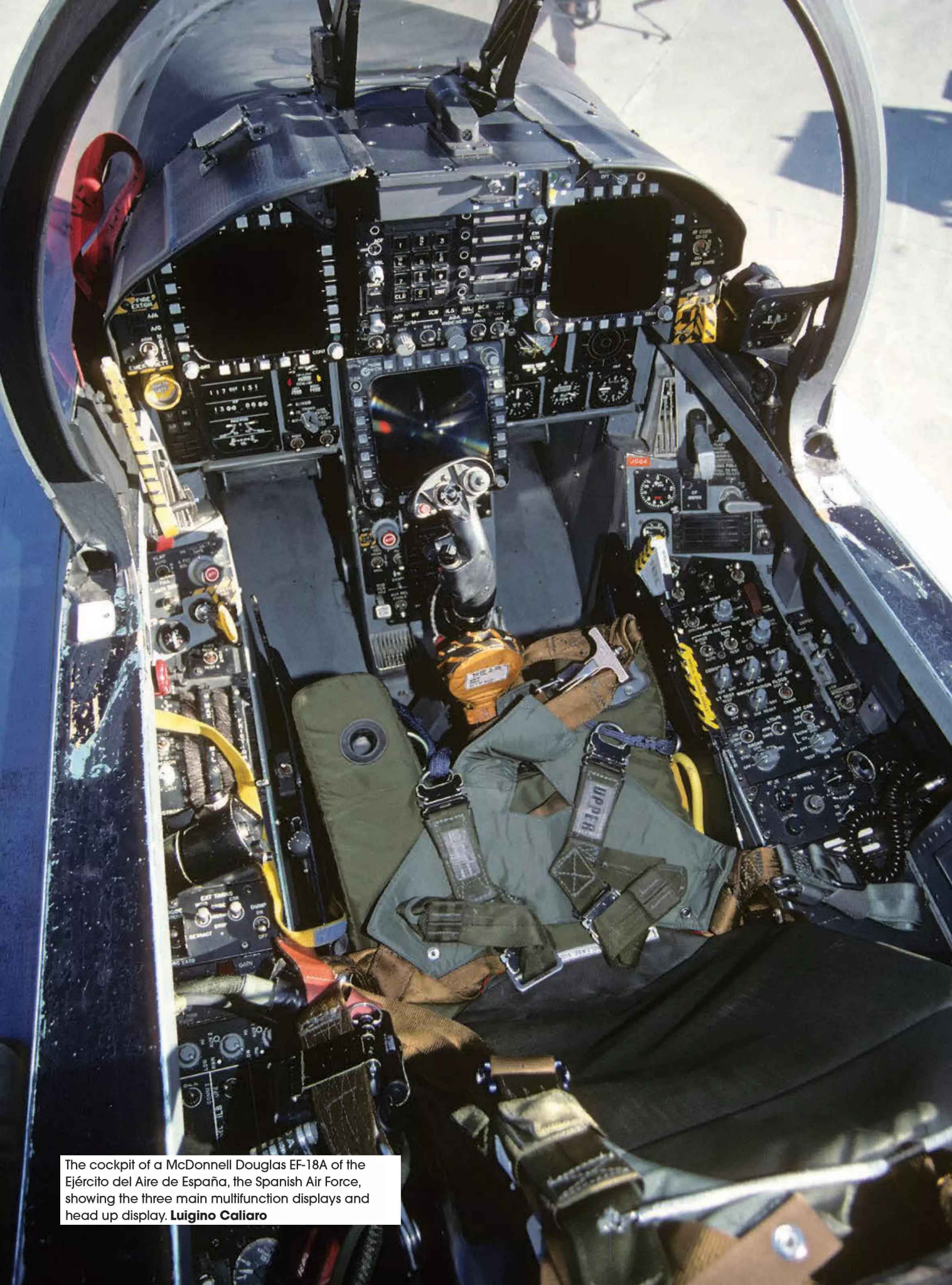

The cockpit of a McDonnell Douglas EF-18A of the Ejército del Aire de España, the Spanish Air Force, showing the three main multifunction displays and head up display. **Luigino Caliaro**

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Probably the best-known public image of the McDonnell Douglas F/A-18 Hornet, the F/A-18As of the US Navy's world-famous demonstration team, the Blue Angels. **Luigino Caliaro**

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MILITARY AVIATION

AIR POWER

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High over Australia, an F/A-18A of 2 Operational Conversion Unit lights its afterburners in the night sky. **RAAF**

Strike Attack
A sting indeed

Writing this publication I have learned an amazing amount about the original Hornet, not least of which is how easy it is to overlook its slim grey shape among the fighters of today. I have also learned that that is a grave mistake. This is an aircraft that gets about its business with a minimum of fuss, that much I have learned, but what a business it is.

There is very little in the way of modern military operations that the F/A-18 Hornet cannot achieve. Fighter, strike, interdiction, maritime patrol, reconnaissance, the Hornet does them all, and does them all extremely well. There were a great many detractors to the F/A-18 programme, the criticisms that have been levelled include the idea that a single aircraft cannot fulfil all the tasks required of a modern military and that this particular aircraft has never had the range required of a carrier-based strike aircraft. Interesting that.

Since it entered service with the US Marine Corps in 1983, the Hornet has been carrying out all the missions it was designed for in conflicts many miles from its carriers. On two occasions F/A-18s were conducting very different operations in separate regions simultaneously. Not bad for a limited capability short range aircraft as some would label it.

The fact of the matter is that Northrop and McDonnell Douglas produced one of the world's great combat aircraft in the Hornet. Flexible, adaptable and supremely reliable, as well as being remarkably cheap to operate, some of the first Hornets built are still flying today, with upgrades ensuring their continued operation.

There is one other thing about the Hornet. It is unbelievably tough, as some of the stories and images in these pages will attest. The basic shape of the aircraft was so right from the start it has changed very little, even in the greatly scaled up F/A-18E, F and G Super Hornets, which, since they are properly a wholly new aircraft, do not feature in this publication. The original Hornet thunders on, its tremendous success, despite its detractors, is perhaps its greatest sting.

As usual on these journeys of discovery, there are a great many people to thank for their illumination and assistance along the way. The media department of the Australian Government's Department of Defence have one of the most comprehensive and beautifully maintained websites and an amazing image library for the Royal Australian Air Force.

Many thanks to them for so many of the superb images that fill these pages, and for their speedy and kind replies to all my enquiries.

All the best,
Tim

Developing a lightweight fighter

Northrop, the F-5, the LWF, and the YF-17

The development story of the McDonnell Douglas F/A-18 is a long and complex one which began with a very different aircraft and a completely different company, the Northrop Corporation.

A Northrop F-5E of the Austrian Air Force shows the leading-edge root extensions that improved the manoeuvrability of the fighter. This was Northrop's first lightweight fighter design and a major success for the company, selling worldwide. **Luigino Caliaro**

Northrop's first jet fighter design produced in numbers was the F-89 Scorpion radar equipped night fighter. These are F-89Ds of the 59th Fighter Squadron, Goose Bay, Labrador. The wing tip pods housed fuel in the rear and air to air rockets in their forward half. **USAF**

The second Northrop X-4 Bantam tailless swept wing research aircraft, two of which were built as part of a NACA high speed flight research programme and were to give Northrop much needed experience with swept wing jet design. **USAF**

The history of the Northrop Corporation up to the early 1950s was one of unbridled success, creating civil and military aircraft in a wide range of types, from transports to jet fighters. In December 1952, John Knudsen 'Jack' Northrop had resigned from the company, Edgar Schmued taking over as vice president of engineering.

He prompted a study into a lightweight, simple but supersonic fighter design, to be known as the N-102, and unknowingly began a development which would eventually lead to the F/A-18. At the time, there was an increase in complexity and operating costs of many modern combat aircraft and their systems and it was foreseen that many countries could not afford these, or if they could, only in very small numbers.

Other companies were looking at the light fighter concept as a way to provide friendly countries with affordable and effective air power. In 1954, NATO held a design competition for a lightweight fighter, but even though several prototypes were produced, the competition came to nothing. However, it did prove that both an interest in and a market for such an aircraft existed.

Welko Gasich, then chief of advanced design, headed the Northrop study team, with designer Lee Begin producing the project drawings. The first design to emerge from his drawing board in 1952 was a high wing tailed delta, powered by a single large turbojet with an air intake below the fuselage, known as the Fang. However, it was considered that the single powerful turbojet engine would be expensive to operate and would require a great deal of fuel.

Tom Jones, who was now Northrop's planning officer and would go on to become its president, then took a hand and changed the emphasis of the programme, with investigation of the lowest cost solutions available taking the lead. Gasich agreed, adding the concept of minimising the life cycle costs over the entire service life of the new fighter, a new approach which

Northrop's first lightweight fighter was the N-156F, an efficient and agile design. Its small head-on profile made it difficult to see and its simplicity made it affordable. **Northrop**

The engineering mockup for the single engined N-102 Fang lightweight naval fighter under construction at the Hawthorne plant. **Northrop**

The second N-156F, 59-4988, seen here after August 9, 1962, when the aircraft officially became the YF-5A and was named Freedom Fighter. **Dave Menard**

was to contribute greatly to the type's later longevity and success.

To address the engine issue, a number of missile projects had prompted the development of small turbojets with high power to weight ratios for the time. One of these was the General Electric J85 and it was decided that two of these engines would make the ideal powerplant for a small, lightweight fighter. In 1955 the Northrop team began work on a series of designs that expanded on this twin engined concept, known as the N-156. The first of these was the N-156TX of March 1955, engines in nacelles under an unswept wing.

Performance studies of the design were disappointing, so it was rejected and the team began work on the N-156NN with engines mounted in the fuselage, fed by separate air intakes. This was intended as a light naval fighter, so was strengthened for carrier operations and featured a T tail and full span flaps. However, the withdrawal from service of the US Navy's escort carrier fleet, the size of carrier for which the aircraft was designed, curtailed interest in the project.

"THE ENCOUNTERS WITH THE LIGHTER AND SIMPLER MIG-17S AND -21S PROVED THAT MANOEUVRABILITY WAS STILL A KEY FACTOR IN FIGHTER DESIGN."

This was followed by six more single and two seat configurations in 1956, the last of which, PD-2879D, was a two-seat design to give the new fighter a training capability, and was very similar to the aircraft that was to eventually emerge. Alongside this two-seat aircraft, a single seat derivative was also being produced, given the designation N-156F, the two-seater being known as the N-156T.

Northrop's interest in a two-seat design had been prompted by a US Air Force (USAF) requirement issued in ➤

The first Northrop YT-38, 58-1191, shows its clean lines and short, trapezoidal wings, a shape that would be a feature of the later lightweight fighter designs. **Northrop**

A Northrop F-5C 'Skoshi Tiger' over Vietnam. It was the air combat experiences of pilots in this theatre and others that were to shape Colonel John Boyd's thinking regarding lightweight fighters and the E-M theory. **Dave Menard**

The two-seat combat trainer version of the F-5 was intended to give pilots experience of flying the full weight aircraft and retained the weapons capability of the single seat version. **USAF**

The MiG-25 Foxbat was a Mach 3 interceptor that caused the USAF to prioritise the development of the McDonnell Douglas F-15 Eagle. **USAF**

Colonel John Boyd, Korean War fighter pilot and father of the E-M theory of combat aircraft design. **USAF**

The VFX programme resulted in the F-111B, intended as a long-range missile armed fighter for the US Navy's fleet defence role. It was the poor agility and sheer cost of such heavy fighter projects that the 'Fighter Mafia' were combating with their lightweight fighter concept. **US Navy**

1955, for a supersonic trainer to replace the Lockheed T-33 Shooting Star then in service with the Air Training Command. The N-156T layout was proposed to the USAF in March 1956 as a response to the requirement, the twin engined layout offering a high safety factor in a trainer. Three prototypes were ordered in July 1956 and a number of revisions were incorporated in the design including the instructor's rear seat being raised by 10in (25.4cm) which gave him an excellent view, the new trainer being designated the now famous T-38 and named Talon.

While the T-38 was in development, Welko Gasich and Lee Begin continued the design of the single seat version of the aircraft under the company designation N-156F. As more data became available from the trainer programme, this was incorporated into the fighter, resulting in a great deal of commonality between the two variants.

As before, cost effectiveness and ease of maintenance were key factors in the design, as was structural strength, to allow overseas customers with tight budgets to maximise the number of aircraft they could buy as well as their length of service. The wing was fitted with the same leading-edge slats and full span flaps of the trainer, but featured a leading-edge root extension or LERX which increased the lift available and improved manoeuvrability in the fighter. This feature is the major identification difference between the types since the T-38 never had them, and was to develop further in later company designs.

There were three other features built in from the start of this design which were unusual for fighters of the day. An arrestor hook was mounted under the rear fuselage to allow engagement with Runway Hydraulic Arrestor Gear (RHAG), to stop the aircraft in icy conditions or in the case of a brake failure. The fighter also had a 15ft (4.6m) brake chute at the rear base of the fin to shorten the landing roll where needed.

The fuel system was designed from the outset to incorporate an air-to-air refuelling probe when required, the probe being available in a kit that could be mounted or dismounted as the operational needs of the customer dictated. Lastly, the fuselage structure had built in hard points to mount jet assisted take off equipment so the aircraft could be operated from short or unprepared dispersed airstrips in time of war.

An additional study was going on at the same time as this design work. ➤

Above: The Northrop P-530 Cobra full size mockup that was displayed at the Paris Air Show in 1971. The aircraft is wearing a spurious Royal Netherlands Air Force serial number. **Northrop**

Right: The McDonnell Douglas YF-15A Eagle prototype, 71-0280.The application of E-M theory to the F-X programme that resulted in this aircraft caused its design weight to be cut by one third. **USAF**

A version was laid out with a larger wing and more internal fuel, along with a fully capable arrestor gear and still further strengthened undercarriage. This was an attempt to introduce a navalised version of the fighter, which was offered to the US and Australian navies in two different formats, an interesting side shoot considering what was to come.

On February 25, 1958, the USAF and the Department of Defence (DoD) ordered three prototypes and a static test airframe under the FX programme, a USAF project that supported the Military Assistance Programme (MAP), a US Government initiative begun in 1949 aimed at providing allied countries with military equipment. The choices of MAP equipment were regulated by the DoD's International Security Affairs Agency (ISAA), who supported the aircraft as the ideal choice for supplying to friendly nations. Northrop also began discussions with a number of countries regarding the licence production of the fighter, which was eventually to be built in Canada, the Republic of Korea, Spain, Switzerland and Taiwan.

At this point, the USAF was supporting a simplified version of the Lockheed F-104 Starfighter for the MAP programme and not the N-156F, which caused Northrop to slow the programme down as the company had been funding the development on its own prior to the order for the three prototypes. The US Army's interest ended when the USAF would not agree to the army operating its own fixed wing aircraft, a position supported by the DoD. The army therefore developed helicopters and the project was dropped.

Although this ended official interest in the single seat version of the aircraft, the Kennedy administration then decided a new, low-cost export fighter was required for the MAP. The ISAA of the DoD informed Northrop that the N-156F was the victor of the resurrected FX programme on April 25, 1962, then on August 9 gave it the official designation F-5 and the official name of Freedom Fighter.

The first production Northrop F-5A, 63-8637, made its first flight in October 1963, while the design of a two-seat version of the fighter, known as the F-5B, was begun. It had been decided that a trainer version of the full weight fighter airframe would be a far better platform to introduce trainees to the handling of the fighter than the much lighter T-38. The F-5B also retained the operational capabilities of the single seat F-5A, enabling it to fill a dual role as trainer and strike aircraft. It was to be further developed into a radar equipped fighter with the introduction of the single seat F-5E and two seat F models in 1972.

Altogether, Northrop and its partners in other countries built 3809 F-5s. This large-scale success came about from the application of sound, simple engineering practices in the airframe from the first design drawings. By keeping all of the costs as low as possible, and by making it possible to maintain the aircraft with basic tools and little equipment, Northrop created a fighter that countries could not only afford to buy, but afford to operate. By creating this light, simple fighter, Northrop had placed itself in an ideal situation to take advantage of what was to come next.

This engineering model was to drive the company's next developments, and flew in the face of the accepted trends in the development of combat aircraft. In the late 1950s the McDonnell Douglas F-4 Phantom was under development as a medium ranged missile armed interceptor for fleet defence.

The development of air-to-air missiles was seen by many as the end of the era of the agile dogfighter and the need for

Lockheed's entry into the LWF competition was the CL-1200 Lancer, based on the X-27, itself a stretched development of the F-104 Starfighter design. **Lockheed**

The Boeing Model 908-909 was a front runner in the LWF competition at one stage. **Boeing**

Designed by a General Dynamics team led by Robert H. Widmer, the YF-16 was a lean and aerodynamically efficient fighter from the very beginning. **USAF**

The first prototype of the Northrop P-600, later designated the YF-17, showing the large leading edge root extensions (LERX) and the cannon repositioned to the top of the nose. **USAF**

fighters to be armed with cannon. In 1961, the USAF's F-X long range fighter programme was merged into the US Navy's to become the TFX, which led to the development of the General Dynamics F-111. This project was intended as a missile platform in the 60,000lb (27,216kg) class, rather than a traditional fighter.

This philosophy was further reinforced in 1963 with a USAF study called Project Forecast, aimed at identifying and prioritising research and development efforts to produce the types of aircraft most likely to be needed in projected conflicts. Both this project and those run by the US Navy had concluded that missile armed F-111 and F-4 variants would fulfil the needs of air and fleet defence for the next two decades. Fighters were set to become little more than heavy launch platforms for missiles.

However, the real-world experience gained in air combat over Vietnam was to upset this theoretical apple cart. The need to visually identify aircraft in combat due to limitations in IFF technology, the very restrictive rules of engagement and the unreliability of the missiles available at the time all meant that US fighters were drawn into close combat with North Vietnamese aircraft far more often than the planners had foreseen. Encounters with the lighter and simpler MiG-17s and 21s proved that manoeuvrability was still a key factor in fighter design.

During this period, former Korean War fighter pilot Colonel John Boyd and Thomas Christie, a mathematician at Eglin Air Force Base, had been using the high-speed computers at Eglin to develop their theory of Energy-Manoeuvrability (E-M), which was published in 1964. This theory modelled actual or projected aircraft performance by relating thrust, weight, drag, wing area and other affecting characteristics to allow an aircraft's performance to be described in terms of kinetic and potential energy.

Aircraft Specific Energy as it was known, when combined with extreme manoeuvrability, the ability to rapidly change speed, height and direction, would enable a fighter to initiate or control any engagement. One of the key factors in this performance theory was airframe weight, as this had a direct effect on both turning radius and acceleration. The calculations enabled performance envelope graphs for any aircraft to be produced, which could then be compared, revealing advantages and disadvantages between types in combat.

One of the early revelations of this theory was how poorly the F-111 would perform in any kind of close combat, largely due to its excessive weight.

These findings caused the USAF to re-establish the F-X requirement independently of the TFX programme, rewriting it to cut the weight by over a third to 40,000lb (18,144kg) and specify a maximum speed of between Mach 2.3 and 2.5, changes that would result in the superb McDonnell Douglas F-15 Eagle in July 1972.

The US Navy cancelled the TFX programme in 1968, beginning the VFX project which rapidly resulted in the powerful Grumman F-14 Tomcat in December 1970. Boyd and Christie were joined by statistician and researcher Pierre Sprey, test pilot Colonel Everest Riccioni and engineer Harry Hillaker to form the core of a group commonly known as the 'Fighter Mafia' who were to lobby for the development of a lightweight, simple pure fighter aircraft throughout the late 1960s. Quite how much of an influence this group had on the development of US combat aircraft in the 1970s is a matter of conjecture. ➤

The size of the likely order for the expanded ACF programme attracted a number of manufacturers to submit proposals, including Saab with the 35E 'Eurofighter' version of the Saab JA 37 Viggen as seen here. **Saab**

For example, their belief that an overwhelmingly large force of simple cheap fighters was the solution to the vast numbers of aircraft the Soviet Union could field was not supported by either the USAF or US Navy. Both services raised questions about the experience and provenance of the group.

Riccioni had no combat experience and Sprey little experience of aircraft design or military requirements prior to joining the group. With hindsight it is possible to see that in the modern electronic warfare environment, such a simple but manoeuvrable fighter as the one they advocated would be at as great a disadvantage as the overweight missile platforms they were so critical of. However, the major achievement of this group was to widely promote and publicise the E-M theory and so achieve a more balanced approach to fighter design by providing the polar opposite to those that advocated missile technology only solutions.

The USAF had actually begun an Advanced Day Fighter (ADF) study in 1965 as it had by then been realised that the most cost-effective fighter force would be a mix of high and low technology aircraft that complemented each other in role while allowing sufficient numbers to be obtained to fulfil the complete spectrum of likely missions. However, the discovery in 1967 of the MiG-25 and its potential performance had caused the DoD to prioritise and concentrate on the F-15 development as a counter to the new threat.

Despite this, in 1969, Colonel Riccioni secured $149,000 to fund the awkwardly named 'Study to Validate the Integration of Advanced Energy-Manoeuvrability Theory with Trade-Off Analysis'. The money was split between Northrop and General Dynamics to study the building of a pure fighter to the exacting requirements of the E-M theory – more of which later.

To return to Northrop and its lightweight fighter developments, in 1965 Lee Begin and his team had begun investigating a stretched version of the F-5 under the internal designation N300. The success of the F-5 and the adaptability of the design had proved that the market for such an aircraft was extensive.

The N300 basically stretched the fuselage to accommodate additional equipment and the more powerful 9000lb (4082kg) thrust General Electric GE15-J1A1 engines. The low wing of the F-5 had limited the size and length of the weapons the aircraft could carry, so the wing was moved to a shoulder position above the air intakes to provide greater ground clearance for ordnance. Small LERX were fitted ahead of the wing as with the F-5 to increase the manoeuvrability of the new design.

This initial study developed further into the P-530, which was a much larger machine. The Northrop design showed its lineage in a number of ways, not least in the nose and cockpit section and the close mounted pair of engines in the rear fuselage with individual intakes.

The power was provided by a pair of low bypass 13,000lb (5897kg) thrust General Electric GE15-J1A5 turbojets, the bypass air providing a cooling effect for the rear fuselage. This was a lesson from the F-5 and was to allow the engine bay to be built with less heat shielding and therefore at reduced weight.

The P-530 also had a similar wing shape to the F-5, a trapezoid, but it was more than twice the area of the original. The design began with wing mounted high on the fuselage, but as it developed this was moved down to a mid-fuselage position.

The leading edge of the inner wing was extended in two large LERXs, which ran from the wing forward to the cockpit where they tapered into the forward fuselage. These gave the aircraft the ability to manoeuvre at angles of attack in excess of 50° and their increase in area provided

50% more lift, as well as directing airflow into the engine intakes at the extreme angles of attack the aircraft could reach. The oversized LERXs also gave the design a hooded look from certain angles, leading to the nickname of Cobra.

The original P-530 had a single fin, but wind tunnel testing showed that at the high angles of attack the aircraft was capable of reaching this would be in the wake of the wing and fuselage. Twin fins were substituted, angled outwards at almost 45° above the otherwise conventional all flying tailplane. As the design developed, by 1969, at the time Northrop received the funding from the E-M study initiated by the 'Fighter Mafia', these fins had grown by almost twice the area and moved forward so they now overlapped the rear portion of the wing.

With the aims of the study now incorporated into the design concept, by 1970 the fins were made larger still but with the outward angle being reduced to 18 degrees. At the same time, the simple slab tailplanes were increased in size and moved as far aft as possible. To maximise the manoeuvrability of the Cobra it was designed with relaxed static stability, the aircraft actually being unstable longitudinally with a marked tendency to pitch up. In keeping with the philosophy of simplicity and because the fly by wire systems of the time were not deemed sufficiently reliable, the controls were all operated by a mechanical system.

The P-530 was aimed at the export market, being intended to replace the Lockheed F-104 Starfighters and Northrop's own F-5s then in service. The design was unveiled on January 28, 1971, and a full-scale mock-up was displayed at the 1971 Paris Air Show, but no customers were forthcoming. However, this was not to be the end of the concept, as other factors were about to take a hand.

As this work was going on at Northrop, the USAF's ADF programme had been revitalised and renamed as the F-XX, largely due to the support of the Defence Secretary Melvin Laird and his deputy David Packard. Packard was a reformist who understood the E-M Theory and the concept of a mixed fighter force, as well as preferring the concept of competitive prototyping for deciding future acquisitions.

In May 1971, just prior to the Paris Air Show, Congress supported the development of a lightweight fighter, granting the addition of $12 million to the 1972 fiscal year budget for the aircraft. The Air Force Prototype Study Group (AFPSG) was also established at this time, with Colonel John Boyd, father of the E-M theory, as a member.

The programme, now known as the LWF, met with considerable resistance from the advocates of the F-15 who saw the new fighter as a threat to the larger aircraft project. In spite of this opposition, the AFPSG released a Request for Proposals (RFP) on January 6, 1972, which invited companies to submit designs for a fighter in the 20,000lb (9072kg) class.

Experience distilled from air combat over Vietnam, Israel, India and Pakistan helped to define the new aircraft, which was to be optimized for air-to-air combat at a speed of between Mach 0.6 and 1.6 at between 30,000 and 40,000ft (9144 to 12,192m), these parameters having shown themselves to be the most common scenario for engagements in the battles fought thus far between modern combat aircraft. The new designs also had to have excellent acceleration, turn radius and range, and where possible, employ composite materials and other emerging technologies in both their construction and equipment.

Five of the largest US aircraft manufacturers produced designs in response to the RFP, despite there being no production plan nor any guarantee that the USAF would order the resulting aircraft at that time. The five were Boeing, General Dynamics, Lockheed, Northrop and Ling-Temco-Vought. Two of the proposals, the Lockheed CL-1200 Lancer, based on the X-27, itself a stretched development of the F-104 Starfighter design but with a larger high mounted wing and low mounted tailplane, and the Vought V-1100, looking uncannily like a cross between its own F-8 Crusader and an F-16, were eliminated from the competition in March 1972.

Obviously, both Northrop with its Model P-600 and General Dynamics with its Model 401 had a head start in the competition thanks to their participation in the earlier E-M design study, but Boeing was a surprise front runner for some time with its Model 908-909. The Boeing entry was also similar in appearance to an F-16 but with a longer swept wing, a more tapered nose and rounder rear fuselage.

Also like the General Dynamics entry, the Boeing Model 908-909 used the Pratt & Whitney F100 turbofan, the same engine intended for the F-15, so having the advantage of a greater commonality of spares and tools for the USAF. However, after considerable further research by the Source Selection Authority, and with the original intention that the LWF programme should embody emerging technologies firmly in mind, Secretary of the Air Force Robert Seamans announced the General Dynamics and Northrop submissions were selected for further development on April 13, 1972.

Two prototypes of the General Dynamics Model 401-16B and the Northrop P-600 were ordered as the YF-16 and YF-17 respectively, General Dynamics receiving $38 million and Northrop $39 million to build the aircraft. The Y or development prefix was used, as opposed to the X or experimental prefix, to indicate that these aircraft were a mixture of existing off the shelf and experimental technologies.

To produce the P-600, the Northrop team modified the P-530 to optimise it for the air-to-air role. In keeping with the E-M theory, the airframe of the YF-17 was kept as light as possible with the use of graphite epoxy composites in many components, including the structure of the LERX and the leading and trailing edges of the wings and fins. The undercarriage was modified to reduce weight and the M61 Vulcan ➤

The close pairing of the General Electric YJ101 engines in the YF-17 meant that the yaw caused by the loss of power from one engine was minimised. **USAF**

Dassault also entered the ACF competition with a SNECMA M-53 engined version of the Mirage F1. **Dassault**

The evaluation trials between the YF-16 and -17 covered all aspects of military flying, including air-to-air refuelling stability as seen here from a Boeing KC-97 tanker. **USAF**

20mm cannon was moved from the underside of the fuselage to the top of the nose ahead of the cockpit.

The flight control system was also changed, the original mechanical actuation being replaced by a partial fly by wire system. Power was provided by a development of the GE-15 used in the P-530, the General Electric YJ101-GE-100 turbofan, which produced 15,000lb (6804kg) of thrust with afterburner. The twin engines were mounted close together in the rear fuselage to minimise any yaw resulting from the loss of the thrust from one engine, and were designed to be easily removed from below the fuselage to ease maintenance.

Northrop engineer Bill Roth had headed the design of a single engined version, the P-610. This was again powered by the Pratt & Whitney F100 intended for the F-15, like General Dynamic's rival design, but this was not selected for the competition. Construction of the two P-600s, now known as the YF-17, began as soon as the contracts were issued, the first aircraft being rolled out at Northrop's Hawthorne plant on April 4, 1974.

While this design and development work was going on, other interests were to significantly affect the programme. The first of these came from the NATO partner countries of Belgium, Denmark, the Netherlands and Norway, all of whom were seeking a replacement for their Lockheed F-104 Starfighters in the fighter-bomber role.

At the beginning of 1974, the four nations agreed that if the US Air Force ordered the winner of the LWF competition, they would also consider it, forming a Multinational Fighter Programme Group (MFPG) to study the options then available.

At the same time, it became clear that the USAF's own fleets of Republic F-105 Thunderchief and McDonnell Douglas F-4 Phantom fighter-bombers also required replacement, so, in the same month the YF-17 was rolled out, James Schlesinger, then Secretary of Defence, announced that the LWF programme was to be redesignated the Air Combat Fighter (ACF), to include ground-attack capabilities and produce a multirole aircraft. Importantly, Schlesinger also underlined that the ACF was intended as a complement to the F-15, which at the time was purely intended for the air superiority role, ending US opposition to the programme.

At the same time, the US Navy and Marine Corps were also seeking a replacement for their range of fighter-bombers and attack aircraft, a project known as VFAX, the second programme with that title. This programme will be covered in more detail later in this publication, but suffice to say for now that in August 1974, Congress decided that a more cost effective solution would be to combine the USAF and US Navy programmes, VFAX becoming the Navy Air Combat Fighter (NACF), a navalised version of the ACF competition winner.

The addition of the NATO partners and the naval variants made the ACF/NACF an incredibly lucrative programme with the potential for order numbers to easily reach thousands of aircraft. This attracted a number of other competitors, including the Dassault Mirage F1 M-53, the SEPECAT Jaguar, the Saab 37E 'Eurofighter' version of the Viggen and another from Northrop, which offered the earlier P-530 Cobra to the MFPG for the NATO nations. The P-530 and Jaguar were not selected for study, but the two-horse race had suddenly become a four way contest.

The importance of the competition was underlined by the USAF's announcement on September 11, 1974, that it intended acquiring the ACF winner in numbers sufficient to equip five tactical fighter wings. This first official interest in a production order also served to give the programme a tremendous boost in confidence, both of the manufacturers and that of potential partner nations. The USAF had originally intended that the test and evaluation period of the General Dynamics and Northrop prototypes would culminate in a decision in May 1975.

However, the European partner nations requested that this be brought forward to December 1974, as their need to replace their existing aircraft was pressing. The General Dynamics design team under Robert H. Widmer had been making rapid progress with the first prototype of the YF-16, which had flown accidentally for six minutes on January 20, 1974, during a high-speed taxi trial by test pilot Phil Oestricher.

The YF-16 and YF-17 prototypes in the air together giving an impression of the difference in the size of the aircraft. The YF-17 was 56ft (17m) long, 6ft 7in (2m) longer than its counterpart and 2ft 2in (0.66m) greater in wingspan at 35ft (10.6m). **USAF**

He took the aircraft into the air rather than risk damaging the prototype after the YF-16 had started to veer off the runway having been subject to an uncontrolled roll oscillation. The official first flight took place on February 2 and was followed by the second YF-16 on May 9. Northrop was not far behind, and after over 5000 hours of wind tunnel and other testing to refine the design, the first YF-17, 72-1569, took to the air for the first time on June 9, 1974. The 61-minute flight took place at Edwards Air Force Base in the hands of Henry 'Hank' Chouteau and was followed by the second aircraft, 72-1570, on August 21.

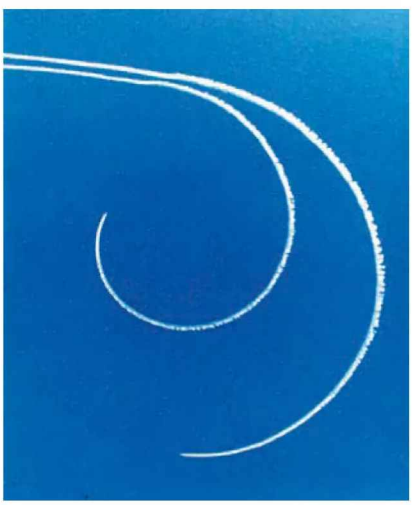
In response to the request of the NATO nations, the USAF had agreed to an accelerated programme of comparative flight trials. These were exhaustive, including many air-to-air sorties against a variety of other types, including the F-4 Phantom and a number of MiG-17s and 21s that had been acquired from various sources by the USAF.

After the initial test flying had been successfully carried out, most of the comparative trials were not flown by test pilots but by regular USAF pilots, all of whom would fly both types to give a service level evaluation of the two aircraft. The YF-16s completed 330 evaluation flights totalling 417 hours in the air, while the YF-17s flew 288 times over 345.5 hours. Every aspect of the performance of the prototypes was studied in detail, both showing some remarkable capabilities.

The YF-17 was capable of a top speed of Mach 1.95 and could reach 50,000ft (15,240m). The refined aerodynamics and additional lift provided by the LERX enabled it to be flown at 34-degree angle of attack in level flight or up to 63 degrees in a climb. Both aircraft were the first fighters to be designed to sustain 9G turns, the YF-17 reaching a peak load of 9.4G during the trials. Despite the excellent performance and handling of the YF-17, the YF-16 proved to have the advantage in range and in manoeuvre performance, especially at supersonic speed, being able to transition more quickly from one manoeuvre to the next.

The YF-16 also offered lower operating costs and the advantage of having an engine in common with the F-15, which was just entering service testing with the USAF. Ultimately, the YF-16 was the choice of all the pilots who flew both aircraft, so on January 13, 1975, Secretary of the Air Force John L. McLucas announced the YF-16 as the winner of the ACF competition. The F-16, now built by Lockheed, was eventually given the name Fighting Falcon but more commonly known as the Viper. It would eventually be ordered by 26 countries worldwide and over 4500 would be built, its success as a design underlined by the fact that it remains in production today, over 40 years after its first flight.

Northrop's disappointment in the loss of the ACF competition was tempered by the fact that it was far from the end of the YF-17 project which was still in contention for the NACF programme. That was to be a different story for the company, as will be related next.



One of the main aims of the ACF programme beautifully demonstrated as an F-16 turns far inside an F-4. **USAF**

One other related development is worthy of note. In an attempt to repeat the success of the F-5 in the export market, Northrop entered the Intermediate Export Fighter or FX competition with a re-engined version of the F-5, known as the F-20A Tigershark, the first flight taking place in 1982. This project too was to come to naught but by that time the company was already busy with the development of the B-2 Spirit stealth bomber.

■ Words: *Tim Callaway*

From YF-17 to the F-18

VFAX and the Navy Air Combat Fighter

Having lost the USAF's ACF competition to the YF-16, the YF-17 was still under consideration for another and somewhat different role, that of a carrier-based strike fighter for the US Navy and US Marine Corps.

As covered in the previous article, in August 1974, Congress merged the US Navy's VFAX programme into the USAF's Air Combat Fighter (ACF) competition, VFAX becoming known as the Navy ACF (NACF). VFAX stood for naval fighter attack experimental and this was not the first project with this title.

In its first iteration in the early 1960s VFAX was intended to produce a replacement for the McDonnell Douglas F-4 Phantom II in the fighter and ground-attack roles, a lighter and cheaper aircraft aimed at supplementing the much larger General Dynamics F-111B in its fleet defence role. The F-111B had emerged from the TFX or Tactical Fighter Experimental programme between the USAF and US Navy.

This joint programme was not a happy affair, having been forced on the two services in February 1961 by the then Secretary of Defence Robert Strange McNamara. The result, in the fighter version, was a large, heavy, unmanoeuvrable missile platform which did not meet the needs of the navy in any way.

Eventually, after many trials and modifications aimed at producing an acceptable fighter, in July 1968 the naval component of the TFX was cancelled. The USAF was to continue with the F-111 as an excellent all-weather low-level strike aircraft and, as previously mentioned, had its F-X programme which would produce the McDonnell Douglas F-15 Eagle air superiority fighter to meet its interceptor and air defence needs.

The US Navy had the VFAX programme, but no other project aimed at producing a pure fleet defence fighter. The massive long-range AIM-54 Phoenix air-to-air missile and its attendant Hughes AN/AWG-9 radar and fire control system developed for the TFX were seen as being vital components in the future naval fighter, which also needed to be a long-range aircraft with a long loiter time.

This was due to the advent of long-range stand-off missiles developed by the Soviet Union which meant that the defensive perimeter required for fleet security was greatly increased in size. However, the weight of these systems meant that any fighter capable of carrying them would necessarily be a large aircraft.

Clearly, this meant that the lightweight VFAX fighter-bomber specification would not be met by any fighter with the required capabilities. Instead, the US Navy dropped the original VFAX concept and wrote the VFX requirement in July 1968, aimed at acquiring the air superiority and fleet defence fighter that would properly meet its needs.

The lessons of air combat over Vietnam had been learned well, in as much as the VFX requirement put air superiority first and fleet defence second. Yes, the new fighter would have to be large to carry the heavy fuel load, missiles and systems, but it would also have to be highly agile and capable of dominating in visual range combat.

The product of the TFX programme, the General Dynamics F-111B was a huge aircraft, the empty weight was 46,100lb (20,910kg), but the maximum take-off weight was an enormous 88,000lb (39,900kg). This was way in excess of the stipulated design specification. **US Navy**

One of the elements of the TFX programme that the US Navy wanted to keep was the long-range AIM-54 Phoenix air-to-air missile seen here under the wing of an F-111B in prototype form as an XAIM-54A. **USAF**

How to achieve these two, in some ways opposing, goals would require a remarkable aircraft. In the TFX project, General Dynamics had needed a partner with experience of producing carrier-based aircraft for the F-111B variant, so had approached one of the great manufacturers of naval aircraft, Grumman.

This partnership gave Grumman an advantage in the VFX programme as it already had experience of working with the TFX's missile and radar systems, as well as the now mature Pratt & Whitney TF-30 engine. As the problems with the TFX became increasingly evident, the US Navy had asked Grumman to begin investigating alternative designs as early as 1966.

They took the engines and weapons system components and moulded them into a new variable geometry design, initially known as the Grumman 303, eventually to become famous as the F-14 Tomcat. Fast, agile and very long ranged, the F-14 was exactly the fighter the US Navy needed.

A number of factors became clear as the F-14 developed. While it was perfectly capable of acting as a long-range strike aircraft as well as a fighter, it would be far too expensive to replace all the strike aircraft the US Navy and Marine Corps required.

These included the Ling Temco Vought A-7 Corsair II, the Douglas A-4 Skyhawk and the McDonnell Douglas F-4 Phantom II, all three of which were not only aging, but the maintenance of such a diverse fleet of types was beginning to prove prohibitively expensive. Consequently, the ground-attack capability would not be developed in the F-14 until its later models and it would remain a pure fighter initially.

The USAF's realisation in the late 1960s that the most cost-effective fighter force would be a combination of high and low technology aircraft was a lesson not lost on the navy. The concept was that a mixture of complex air superiority fighters and lightweight fighter-bombers would fulfil all the required roles at the same time as allowing sufficiently large numbers of aircraft to be acquired. The experiences of the Vietnam War had also validated the concept of the dual role strike fighter as being the most survivable type of attack aircraft in an environment where air superiority had not previously been established.

A test drop of the AIM-54 Phoenix air-to-air missile from an F-111B. The other element the US Navy wanted to keep from this aircraft was the powerful Hughes AN/AWG-9 radar and fire control system mounted in the nose. **US Navy**

These factors led the Naval Air Systems Command (NAVAIR) under Vice Admiral Kent Lee to strongly advocate the reinstatement of the VFAX programme in the early 1970s.

Lee was to meet a similar opposition to the programme as that experienced in the USAF by the Lightweight Fighter (LWF) project, and for very similar reasons. ➤

The utterly superb Grumman F-14 Tomcat was the result of the VFX programme of July 1968, seen here carrying its maximum load of six AIM-54 Phoenix missiles. This load was unlikely on carrier operations as the weight was prohibitive. **Warren Thompson**

An artist's impression of the Vought Model 1600, the navalised version of the YF-16 intended for the NACF competition. **Vought**

Despite being constrained as an air superiority and fleet defence fighter, from the start the F-14 was capable of carrying a wide variety of ground-attack munitions as the image of an F-14A at NAS Point Mugu in 1972 clearly demonstrates. **US Navy**

In the USAF, the LWF was seen by some as a potential threat to acquisition of the F-15, in the US Navy the resurrected VFAX was seen as a threat to the F-14. As with the LWF programme, the opposition to VFAX ended when Congress took a hand, directing the navy to seek a cost-effective strike fighter in August 1973.

It was made clear that this was not intended as an alternative to the F-14, but as a complementary fighter that would fulfil the strike role and enable a larger mixed force to be acquired. As a result, a new VFAX specification was drawn up and a Request for Proposals (RFP) was issued to industry in July 1974.

Grumman responded with the F-14X, a stripped-down attack version of the fighter, and McDonnell Douglas proposed a navalised F-15, but both aircraft were almost as expensive as the standard F-14 and neither met the lightweight and cost effective elements of the VFAX requirement.

The new VFAX programme was to be very short lived. In April 1974, the USAF's LWF programme had been redesignated as the Air Combat Fighter (ACF), which essentially turned a pure fighter into a fighter-bomber by adding a strike capability.

Given the similar nature of the ACF and VFAX requirements, on August 28, 1974, only a month after the RFP, Congress instructed the navy to select one of the ACF competitors as the most cost-effective solution; the funding for the VFAX programme being diverted to what was now known as the Naval ACF or NACF.

Given the previous experience with the disastrous joint TFX programme, this decision met with some scepticism for understandable reasons. However, unlike the TFX which tried to turn a long-range strike aircraft into a naval fighter, in this case the needs of the two services were closely allied, both were seeking a lightweight, affordable strike fighter.

This of course massively increased the likely market for the ACF, so interest from industry was intense. Neither of the two competing companies, Northrop and General Dynamics, had experience or expertise in producing carrier-based aircraft, so both sought partners to jointly develop their ACF entries for the NACF. Grumman was busy with the development and introduction into service of the F-14, so General Dynamics teamed with Ling Temco Vought, manufacturer of the A-7 Corsair II attack aircraft and F-8 Crusader fighter, while Northrop approached McDonnell Douglas which had built the A-4 Skyhawk and the extremely successful F-4 Phantom II.

General Dynamics and Vought developed the YF-16 design as the Vought Model 1600, proposed in three variants. The Model 1600 was powered by the Pratt & Whitney F401 afterburning turbofan, the engine originally intended for the production version of the F-14. This was a naval development of the F100 engine for the F-15, which was also the powerplant of the second version of the Vought design, the Model 1601.

The third version, the Model 1602 was to be powered by the General Electric F101, the engine developed to power the Rockwell B-1A bomber. This version also featured an enlarged fuselage to accommodate improved avionics and more fuel to better meet the US Navy's range requirements. After the YF-16 won the ACF competition in January 1975, the Model 1602 was further developed into the Model 1602B in March, which had yet more modifications to the fuselage and wing structure.

All three variants would be capable of carrying the AIM-7 Sparrow missile, which would necessitate the development of a radar system compatible with the Sparrow's Beyond Visual Range (BVR) capabilities as this ability was not part of the USAF's ACF specification. All of the variants had strengthened fuselage and wing structural elements as well as a stronger undercarriage and an arrestor hook to cope with the tremendous stresses of carrier borne operations.

At the same time, Northrop had begun modification of the YF-17 design to meet the NACF requirement, initially known as the P-630. With the involvement of McDonnell Douglas in the design process, this became the Model 267 which, while retaining the basic shape of the YF-17, featured a large number of structural changes.

The airframe and undercarriage were strengthened and the original arrestor hook intended for use with airfield equipment was beefed up to take the forces of carrier landings. The track of the mainwheels was also widened for better stability on carrier decks.

To reduce the space the aircraft required in carrier hangars, a wing fold

The Vought A-7 Corsair II attack aircraft was one of the aircraft the VFAX programme was aimed at replacing. **US Navy**

The McDonnell Douglas F-4 Phantom II also needed replacing through the VFAX programme. This is an F-4J of VF-96, armed with AIM-7 Sparrow and AIM-9 Sidewinder missiles, the weapons intended for the VFAX winner. **US Navy**

The competition for the USAF's ACF had included ground-attack trials which was a major part of the US Navy's requirement for the VFAX and its replacement the NACF programme. Here the first prototype of the Northrop YF-17, 72-1569, makes a strafing run firing its M61 Vulcan 20mm cannon. **USAF**

The shape of things about to come. The McDonnell Douglas Model 267 proposal was a very different aircraft to the YF-17, the larger wings and greater diameter forward fuselage being evident in this view. **Keith Draycott**

The second prototype YF-17, 72-1570, was repainted in a US Navy scheme while being evaluated for the NACF programme. It is seen here with Northrop's earlier successful lightweight fighter, an F-5E chase plane. The evolution of the design is evident in this shot. **Northrop**

mechanism was fitted just outboard of the inner end of the ailerons.

A 96-gallon (364 litre) fuel tank was added in each inner wing to increase the fuel capacity to meet the NACF range specification for the escort fighter and strike attack roles. The spine behind the cockpit was enlarged and the rear fuselage widened by 4in (10.1cm) to allow greater room for fuel and avionics and also to allow the engines to be angled inwards slightly towards the rear.

A lesson from the F-15, which suffered from tailplane flutter in its early version, meant the leading edge of the wing and tailplane were 'dogtoothed', an extension in chord that notched the leading edge at about two thirds span of the wing and close to the fuselage of the tailplane were intended as aerodynamic cures for this phenomena.

The wingspan was also increased by 5ft 4.75in (1.64m) to 40ft 4.75in (12.3m) which gave a 50sq ft (4.65sq m) increase in wing area. Two pylons for weapons or fuel tanks could be fitted under each wing, along with a centreline pylon under the fuselage and the wingtip launch rails for AIM-9 Sidewinder missiles.

As well as these, a pair of AIM-7 Sparrow missiles could be mounted in semi-recessed mounts on either side of the lower fuselage. The most obvious design change came in the nose section, which was of much greater diameter and less pointed than that of the YF-17 to accommodate the powerful radar required for the larger missiles. It was also decided to replace the partial fly by wire control system of the YF-17 with a fully digital quadruple redundancy fly by wire system, the first such control system fitted to a fighter.

Finally, the engines were changed from the General Electric YJ101s fitted to the YF-17 to its development, the General Electric F404-GE-400 which increased the thrust to 16,000lb (7258kg) with afterburner.

The US Navy had access to all of the flight test data from the ACF competition and navy pilots flew both the YF-16 and YF-17, the second prototype of which had been repainted into US Navy colours.

This still carried the 'Cobra' badge on the nose and many people still referred to the aircraft by this name. Although the YF-16 had won the USAF contest, the competition had been a close one, the results having shown the YF-17 to have a number of advantages, not least in high angle of attack manoeuvring and its greater weapons capacity in the strike role.

The modifications to both designs by Vought and McDonnell Douglas meant that both aircraft now met the NACF specification, but there was one vital factor that was most in the YF-17s favour, simply that it was a twin engined aircraft. This gave the Model 267 a tremendous safety factor for naval operations over its single engined rival.

On May 2, 1975, the US Navy announced that the Model 267 development of the YF-17 was the winner of the NACF competition and would be acquired in three versions under new designations, the F-18 single seat fighter, the A-18 single seat attack aircraft and the two seat TF-18A trainer.

The development work was to continue, with contracts being issued in November 1975 to General Electric for the development of the F404 turbofan, followed in January 1976 to McDonnell Douglas for nine single seat and two two-seat full scale development prototypes. McDonnell Douglas would be the prime contractor on the naval version, while Northrop would lead the development of the land-based F-18L intended for the export market.

A great deal of work still remained to be done before the first aircraft would fly and many more changes were to be made to both the aircraft and its systems, all of which will be covered later in this issue.

■ Words: *Tim Callaway*

The F/A-18 partners

Douglas – from the SBD to the DC-9

Part one

As their partner on the NACF, Northrop chose McDonnell Douglas as a centre of expertise in producing naval aircraft. Formed by a merger of the McDonnell Aircraft Corporation and Douglas Aircraft on April 28, 1967, both of these companies had a history of building excellent carrier-based fighters and bombers. Incidentally, the history of Douglas also included an earlier iteration of the Northrop company.

THE DOUGLAS AIRCRAFT COMPANY

By 1941, Douglas was based in three large plants at Santa Monica, El Segundo and Long Beach all in Southern California, along with leased plants in Chicago, Oklahoma City and Tulsa. These were to produce a range of types including thousands of Douglas C-47s transports, military versions of the DC-3 airliner, which became the logistics backbone of the Allied forces in the Second World War. While the DC-3 had been in development, several other aircraft were being developed and built by Douglas, two of which were to be carrier-based types, continuing the association of the company with the US Navy.

EARLY CARRIER AIRCRAFT

Interest in carrier-based bomber and torpedo aircraft by the US Navy resulted in a competition in 1934. Douglas entered the XTDB low wing monoplane with a crew of three, powered by an 800hp Pratt & Whitney XR-1830 14-cylinder radial. Capable of carrying a 21in (53.3cm) torpedo or 1500lb (680kg) of bombs, the XTDB-1 first flew on April 15, 1935.

Naval trials took place, with the aircraft being returned to Douglas in 1936 for minor modifications. These included raising the canopy slightly to improve pilot visibility, especially on approach to land. The Navy ordered 114 of what was now named the TBD Devastator, production beginning on February 3, 1936. Service aircraft were fitted with the 900hp R-1830-64 engine in a revised cowling.

Fifteen more Devastators were ordered on August 16, 1938, the last being delivered in November 1939. Even as these entered service, it was recognised that the Devastator was already outclassed by the new generation of fighters such as the Messerschmitt Bf 109 and Mitsubishi A6M.

After the Japanese attack on Pearl Harbor on December 7, 1941, the Devastators took part the early battles in the Pacific with some success, sinking the Japanese carrier Shoho on May 7, 1942, during the Battle of the Coral Sea. However, during the Battle of Midway between June 4 and 6, 36 out of 41 Devastators were lost in action without gaining a single hit on the Japanese fleet. The type was immediately withdrawn, the surviving 39 aircraft being used by Atlantic and training units until 1944 after which they were all scrapped, none surviving today.

While the TBD was in development, the former Northrop Corporation, in which Douglas was the majority shareholder, had been purchased outright to become the El Segundo Division of Douglas in August 1937, Jack Northrop resigning to begin his own company. The Northrop designs still in production were redesignated with Douglas model numbers, the Northrop A-17 attack bomber becoming the Douglas Model 8, the A-17A the 8A and so on.

Before the merger, the A-17 had also been developed into the BT-1 carrier-based dive bomber and entered into the same competition as the Douglas TBD. The BT-1 was the first project by the great aircraft designer Ed Heinemann, later to become the chief engineer at Douglas. This in turn became the BT-2 dive bomber with the addition of a new canopy, leading edge slots and a retractable undercarriage.

The US Navy and Marine Corps ordered 144, now known as the Douglas SBD-1, with the last 87 being completed as SBD-2s with greater fuel capacity. The SBD became famous in the Second World War as the Douglas Dauntless, with 5937 being built, 948 for the US Army Air Corps (USAAC) as the A-24 Banshee attack bomber.

A Douglas TBD-1 Devastator of Torpedo Squadron Five (VT-5) pictured in flight. Note the squadron insignia and Navy E on the fuselage beneath the cockpit. **National Museum of Naval Aviation**

Douglas TBD-1s pictured in various stages of assembly at Douglas Aircraft Company's Santa Monica, CA, plant. Note that the aircraft already carry the markings of Torpedo Squadron Two (VT-2), which received its first delivery of Devastators in 1938. **National Museum of Naval Aviation**

WARTIME BOMBERS

Just before the merger in March 1937, Donald Douglas, Jack Northrop and Ed Heinemann led a team to develop a new twin engined light bomber known as the Model 7A. Powered by a pair of 450hp Pratt & Whitney R-985 Wasp Junior radials and intended to carry a 1000lb (454kg) bomb load, it was evident that the concept would be lacking in performance so it was shelved for the time being.

In the autumn, the USAAC issued a requirement for an attack aircraft, so Ed Heinemann took the Model 7A and redesigned it to take the 1100hp Pratt & Whitney R-1830 Twin Wasp engine and doubled the design bomb load.

Known internally as the Model 7B, it initially failed to interest the USAAC, but 254 were ordered by the French Air Force, with a further 16 for the Belgian Air Force after trails in January 1939. This initial concept was further redesigned with a lower mounted wing and larger fuselage as the DB-7. In May 1940, 64 of the French aircraft were used in combat in an attempt to slow the rapid German advance. The remainder of the French order was diverted to the RAF, who used the type to eventually equip 24 Squadrons under the name Boston for the light bomber and Havoc for the radar equipped night fighter.

The type was also to see wartime service with the air forces of Australia, Canada, the Netherlands and South Africa. The USAAC recognised the excellent performance of the DB-7 in its developed form, purchasing large numbers from 1940 onwards as the A-20 light bomber, P-70 night fighter and F-3A night reconnaissance aircraft. The A-20G was developed with a solid nose replacing the bomb aimer's station, containing four 20mm cannon and two .50 cal Browning M2 machine guns as a ground-attack aircraft. ➤

The El Segundo production line in 1943 showing SBD Dauntless dive bombers under construction. **National Museum of Naval Aviation**

After the absorption of Northrop by Douglas, the BT-2 became known as the Douglas SBD, the world-famous Dauntless dive bomber of the Second World War. **Douglas**

A very early Douglas A-20 used by the USAF as a light bomber and ground-attack aircraft. Note the turbosupercharger inlet on the outboard aft engine nacelle. **USAF**

"WHILE THE DC-3 HAD BEEN IN DEVELOPMENT, A NUMBER OF OTHER AIRCRAFT WERE BEING DEVELOPED AND BUILT BY DOUGLAS, TWO OF WHICH WERE TO BE CARRIER-BASED TYPES"

These and the bomber versions were used extensively by the US Army Air Force (USAAF) and the Soviet Air Force, who were to receive 3414 of all the DB-7 models built.

Eventually 7478 of all versions of the agile and fast aircraft were delivered before production ended on September 20, 1944, its delightful handling characteristics making it tremendously popular with pilots. Many components from the DB-7 design were used in the least well known of the Douglas transports, the high wing 16 seat DC-5 which first flew on February 20, 1939.

Twelve of these were built, the prototype becoming William T. Boeing's personal aircraft before it was impressed into service with the US Navy, four going to Dutch national airline KLM before the US entry into the Second World War, the other seven being built for the US Navy and Marine Corps. All were retired in 1946, but one aircraft ended up in Israel and was used during the 1948 Arab-Israeli War.

Production was never resumed because war surplus DC-3s were flooding the civil market. Ed Heinemann then led a team that developed the twin engined attack aircraft concept into one of its most long-lasting designs, the superlative Douglas A-26 Invader.

Like the earlier A-20, this was produced in both light bomber versions with a glazed nose for a crew member acting as both bomb aimer and navigator, and heavily armed solid nosed versions as a powerful ground-attack aircraft.

The prototype first flew on July 10, 1942, powered by a pair of 2000hp Pratt & Whitney R-2800 Double Wasp radials, the A-26 was capable of 355mph (572kph) and could carry a 6000lb (2722kg) bomb load in the internal bay and on pylons under the wings.

Either six or eight .50 cal Browning M2 machine guns could be fitted in the solid nose, along with an additional six in the wings or eight in removable underwing pods. For defence a pair of remotely controlled turrets with two .50 cals were fitted above and below the fuselage just aft of the wing, controlled by the third crew member in the aft compartment behind the bomb bay. Fast and powerful, the A-26 benefited from the laminar flow wing airfoil sections developed by NACA, the wing being designed by A. M. O. Smith.

Altogether 2452 A-26s were built, serving with the US forces throughout the Second World War, the Korean War and even on into the Vietnam War, 40 aircraft being reengineered as A-26Ks to operate as counterinsurgency aircraft. The last A-26s did not leave US service until the Air National Guard retired type in 1972. After the Second World War the B-26, redesignated as the retirement of the Martin B-26 Marauder no longer caused confusion, was acquired by 21 countries in Europe, Africa, Central and South America.

In 1955, nine B-26s became the first operational aircraft of the Royal Saudi Air Force when they equipped 3 Squadron at Jeddah. The Invader was also used by civil organisations in the US, Canada and Norway in roles as diverse as VIP transport, research platform and fire bomber, the last of the Canadian fire bombers not retiring until the late 1990s.

TRANSPORTS AND AIRLINERS

Aside from its own bomber designs, Douglas also built the Boeing B-17 Flying Fortress and the Consolidated B-24 Liberator in large numbers under licence, while the Santa Monica headquarters continued to develop transport aircraft. The complexity of the single DC-4E caused Eastern and United Airlines to request a cheaper, simpler four engined airliner.

Douglas responded with the DC-4 which first flew on February 14, 1942, again at Clover Field with the redoubtable Carl Cover at the controls. This had a single fin, tapered wing, tricycle undercarriage and four 1450hp Pratt & Whitney R-2000 Twin Wasps. Its nearly tubular unpressurised fuselage was intended to carry up to 86 passengers, but the US entry into the Second World War diverted all production to military transport versions, the USAAF's C-54 and the US Navy's R4D.

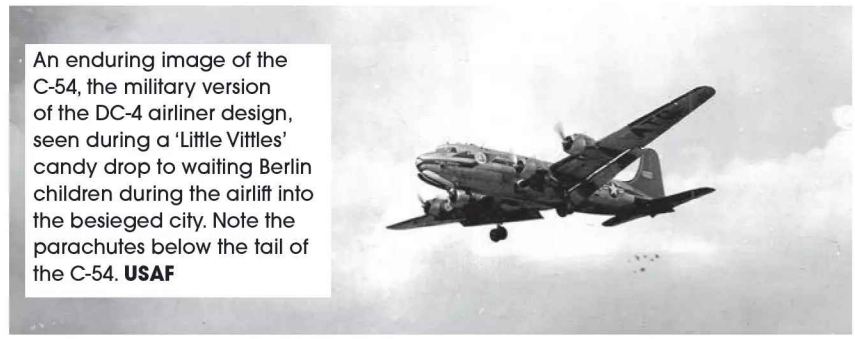
Of these, 1163 were built between May 1942 and January 1946, followed by 79 civil DC-4 airliners in the immediate postwar years. The military versions served with great reliability during the war and became the backbone of the Berlin Airlift, the ease of maintenance and general reliability keeping them in service well into the 1960s. The civil versions and over 500 converted military transports served with airlines worldwide, 13 of which are still in service today with Buffalo Airlines of Canada as cargo transports and fire bombers.

A plethora of sub types were produced or modified, two of which were very different. The first was the Canadair North Star which was powered by Rolls-Royce Merlin 622 V12 engines, the second was the Aviation Traders Carvair, converted from 21 DC-4s and C-54s beginning in 1959. The cockpit was fitted above the existing fuselage, which was extended and fitted with a sideways opening nose door to accommodate up to five cars and

9th Air Force Douglas A-20Gs on a sortie over the French coast. **USAF**

A solid nosed Douglas A-26 Invader attack aircraft dropping bombs on the Siegfried Line in early 1945.The powerful A-26 replaced the A-20 in service. **USAF**

The glass nosed Douglas B-26C (A-26C) Invader on display at the National Museum of the United States Air Force. **USAF**



An enduring image of the C-54, the military version of the DC-4 airliner design, seen during a 'Little Vittles' candy drop to waiting Berlin children during the airlift into the besieged city. Note the parachutes below the tail of the C-54. **USAF**

22 passengers or three cars and up to 55 passengers.

These were used as flying car ferries, initially in the UK, Ireland and Australia, but later all over the world.

The DC-4 was in turn developed into the stretched and pressurised DC-6 powered by the Pratt & Whitney R-2800 Double Wasp, starting with the 1800hp version which rose to 2500hp as the aircraft and engine developed.

From the first flight on February 15, 1946, 704 were to be built, serving initially with the USAF as the C-118 Liftmaster and the US Navy as the R6D, as well as with the major US Airlines.

The rugged simplicity of the design and its engines meant the DC-6s were eventually to serve with the airlines of 77 countries and the air forces of 25 more. Indeed, nine are still in use as cargo aircraft, one in Canada with Buffalo Airlines and eight more in Alaska with Everts Air Cargo while several more are still flying in South America and Europe. The DC-6 was further developed by stretching the fuselage again and changing the engines to the 3250hp 18-cylinder Wright R-3350 Duplex Cyclone to produce the DC-7.

These turbo compound engines as they were known were powerful but unreliable and difficult to maintain; this factor, along with the advent of the first turboprop and jet airliners, meant that production was limited to 338 DC-7s in three main versions. The aircraft had been developed as a response to an American Airlines need for an airliner that could fly nonstop across the US, making its first flight on May 18, 1953.

The wing root was redesigned to improve efficiency and the engine nacelles were moved outboard slightly, to provide better passenger comfort by reducing cabin noise in the DC-7C. Additional fuel tanks were added to increase the range and allow nonstop transatlantic flights, initially being operated by the major US airlines before its range performance attracted such airlines as BOAC, Sabena, Swissair and SAS in Europe.

The speed with which the DC-7 came and went with the major airlines is best illustrated by the fact that the last production aircraft was delivered to KLM in 1958, and by 1959, many DC-7s were being converted by Douglas into the DC-7F freighter version for use by cargo airlines. Eventually 38 nations were to operate DC-7s as they quickly came on to the second-hand market but were relatively new. The earlier DC-6 with its tremendous reliability was retained far longer than its replacement by dint of its greater reliability and cheaper maintenance costs. Several of the freighter versions were also converted as fire bombers, with five still flying in the US as late as 2013.

The C-54 also served in the Korean War, here casualties are loaded into a C-54D at Taegu in 1951. **USAF**

The DC-4 airliner version served with a number of US airlines in the late 1940s and early 1950s, such as Capital Airlines as seen here. **San Diego Air and Space Museum**

GIANTS OF THE SKY

Douglas had also been designing some very large aircraft for the time, the first of these being a response to the USAAC's secret 'Project D' of February 5, 1935, aimed at producing an experimental long-range bomber.

A single four-engined Douglas XB-19 was produced, which, with a wingspan of 212ft (64.6m), was a true behemoth for the time. Funding and development delays meant that approval to build the prototype was not received until March 8, 1938, so construction began, albeit slowly due to the pressure of the other projects Douglas was working on.

The huge single finned aircraft first flew on June 27, 1941, the tapered wing with its swept leading edge looking like that of an enormously scaled up DC-3. The weaponry of the XB-19 was impressive with a maximum bomb load of 37,100lb (16,828kg) and 11 defensive turrets and machine gun positions.

The 16-man crew could be supplemented by a six-man relief crew, ➤

An Aviation Traders ATL-98 Carvair of Aer Lingus, one of 21 converted from DC-4s and C-54s beginning in 1959. The cockpit was fitted above the existing fuselage, which was extended and fitted with a sideways opening nose door to accommodate up to five cars and 22 passengers or three cars and up to 55 passengers. **Adrian Pingstone**

The USAF acquired the DC-6 as the C-118 Liftmaster. One was used as President Harry S. Truman's personal aircraft, the Douglas VC-118 Independence, seen here in 1947. **Harry S. Truman Library**

The ultimate long-range piston engined airliner development, the Douglas DC-7C or 'Seven Seas' was used on intercontinental routes by such airlines as Pan American Airways. **San Diego Air and Space Museum**

The Douglas XB-19 bomber under construction in 1940. **USAF**

who were provided with a compartment with seats and bunks, as well as a galley to supply hot meals in flight.

Experimental trials provided a great deal of data that would later be used in the Boeing B-29 Superfortress and Convair B-36. Initially powered by four 2000hp Wright R-3350 Duplex Cyclone radials, these were replaced in 1943 with four 2600hp Allison V-3420 24-cylinder inline engines at which time the aircraft was redesignated as the XB-19A and consigned to a transport role. It was eventually flown to Davis-Monthan Field in Arizona in 1946, where it was scrapped three years later.

The experience with the XB-19 was to prove useful to Douglas in developing two very large military transport aircraft. The first of these was in response to the need for a heavy lift cargo and personnel transport with very long range that arose from the US entry into the Second World War and the global nature of the conflict.

Douglas formed the 'C-74 Project Group' in January 1942, who took the DC-4 design and essentially simplified and enlarge it to become a transport for two light tanks or two 105mm howitzers with tractors and crews, or up to 125 troops or 115 stretchers. Loading and unloading were facilitated by the internal twin cranes that could travel the length of the fuselage and by the large cargo lift built into the lower fuselage just aft of the wing.

The USAAF awarded a contract for 50 C-74s, named Globemaster, in June 1942 based on the proposal. The first production aircraft flew on September 5, 1945. No prototypes were built, but the end of the war and the cancellation of many contracts meant that only 14 were built before construction ceased in April 1947.

Powered by four 3250hp Pratt & Whitney R-4360 Wasp Major 28-cylinder radial engines, the C-74 proved incredibly reliable, being used in support of USAF deployments worldwide. A single example was used on the Berlin Airlift in 1948, setting many records and flying in the large equipment needed to build the third airport at Tegel.

During the Korean War, C-74s flew between California and Hawaii with troops and cargo, returning with wounded personnel. However, the curtailed production run led to a shortage of spare parts, the C-74s being placed in storage at Davis-Monthan Air Force Base in the first quarter of 1956. Ten were scrapped in 1965, but four were sold on the civil market, three operating with Aeronaves de Panama. One of these, 42-65409, appeared in the movie The Italian Job after it had been abandoned at Milan airport in 1969.

The experience of using the C-74 on the Berlin Airlift showed the USAF the need for a very heavy lift aircraft capable of transporting such items as tanks and bulldozers. In consultation with Douglas, it was agreed that the fifth C-74 on the production line would be converted to the prototype YC-124 Globemaster II.

THE GLOBEMASTER II

The wings, tailplane and engines of the C-74 were used but an entirely new double deck fuselage was designed, fitted with large clamshell doors in the lower nose with an automatic ramp which allowed vehicles to be driven directly in or out of the aircraft. The cargo lift aft of the wing was also retained to speed loading.

The first flight on November 27, 1949, and subsequent service trials were entirely satisfactory, the only change between the YC-124 and the C-124A production version being the fitting of upgraded versions of the R-4360 engines which boosted the power to 3500hp. Deliveries of this version, of which 204 were built, started in May 1950.

In 1951, development began of the YC-124B, a turboprop version powered by four 5550hp Pratt & Whitney YT-34 engines which first flew on February 2, 1954. This was intended as an air refuelling tanker, but was not adopted, the USAF preferring to standardise on the Boeing KC-97 Stratotanker. The availability of the 3800hp version of the R-4360 engine meant another 243 aircraft were produced as C-124Cs, with an increase in fuel capacity, a thimble nose radome for a weather radar and wingtip pods for combustion heaters.

Data from the XB-19 project proved useful to Douglas in developing its later large transport aircraft. **USAF**

A Douglas C-74 Globemaster I seen at Los Angeles Airport in 1949. **San Diego Air and Space Museum**

A Douglas C-124A Globemaster II, seen with its clamshell loading doors open. Note this aircraft has been upgraded with the wing tip combustion heater pods. **USAF**

A Douglas C-124C of the US Air Force Reserve 916th Military Airlift Group based at Carswell Air Force Base in Texas. **USAF**

A Douglas C-124C of the US Air Force Reserve 916th Military Airlift Group based at Carswell Air Force Base in Texas. **USAF**

These last two features were retrofitted to many C-124As. Like the C-74, the C-124 proved tremendously reliable, being used to fly nuclear weapons between Strategic Air Command bases among many other roles. Able to airlift much of the US Army's front line equipment, the C-124 stayed in service with the USAF until the last were retired from Air National Guard units in September 1974.

While the capabilities of the C-124 were impressive, there were still a number of large cargoes it could not carry. These limitations caused the USAF to begin seeking a very large strategic cargo and tanker aircraft in January 1951. As noted in the accompanying table, Douglas responded with the C-132 in February 1954.

However, problems with the development of the intended turboprop led to the cancellation of both the engine and the aircraft in 1956. The need to move oversize cargoes still remained, the USAF having formulated the Logistic Carrier Supporting System requirement known as SS402L in 1952.

The engineering data acquired from the C-132 and the YC-124B, both of which were turboprop powered, was put to good use in the Douglas response to this requirement. In February 1953 design work began on the C-133 Cargomaster which shared many of the features of the cancelled C-132 including the undercarriage layout and rear loading doors and ramp.

An uninterrupted 90ft (27m) long cargo bay was achieved by mounting the high aspect ratio wing on top of the fuselage so the structure did not impinge on the internal space. The high mounted tailplane allowed even very large cargoes such as ballistic missiles to be loaded with relative ease. The first flight took place on April 23, 1956, early tests revealing the need to increase the size of the dorsal fin to improve directional stability.

Again, no prototypes were built, the aircraft going straight into production as the C-133A, the first deliveries being made to the 39th Air Transport Squadron at Dover Air Force Base in August 1957. Initially powered by four 5700hp Pratt & Whitney T34-P-3 turboprops, as the 35 C-133As were built these were replaced in the last few aircraft by the 7100hp P-7W version of the engine. As production progressed the rear fuselage was redesigned and on the last three aircraft a new clamshell rear door was introduced that increased the available cargo space by 3ft (0.91m) to allow fully assembled Atlas, Thor and Jupiter ballistic missiles to be carried.

The use of these aircraft to transport the missiles between their bases was far cheaper and safer than using road or rail transport. The next 15 C-133s built between October 1959 and April 1961 also had the new clamshell rear doors but were re-engined with the 7500hp P-9W version of the T34 to produce the C-133B. These were the last of the 50 Cargomasters built, the additional power increasing their load capability over a range of 4000 miles (6437km) to 52,000lb (23,587kg), 10,000lb (4536kg) more than the C-133A. These were extremely hard working aircraft in their 14-year career with the USAF, not only transporting the later Minuteman ➤

The Douglas C-133A Cargomaster on display at the National Museum of the United States Air Force. **USAF**

A Douglas SM-75/PGM-17A Thor Intermediate Range Ballistic Missile is loaded onto a Douglas C-133A Cargomaster transport for airlift to its intended base. **USAF**

The first Douglas DC-8, N8008D, seen at Long Beach after its roll out on April 9, 1958. **San Diego Air and Space Museum**

missiles, but providing logistics support to US deployments worldwide.

They also supported NASA's Mercury, Gemini and Apollo space programmes by transporting rocket boosters to Cape Canaveral in Florida and collecting the Apollo capsules after their return to earth. By 1971, the airframes had begun to suffer from severe fatigue problems, so were withdrawn from service and placed in storage at Davis Monthan.

Plans to use four Cargomasters as flying hospitals by a civilian international aid agency in 1973 were prevented by the extent of the fatigue damage, but in 1976, Northern Air Cargo used a single C-133B to airlift heavy equipment for the trans-Alaskan pipeline.

JET AIRLINERS

With the advent of the de Havilland Comet 1 in 1949 and the interest from Boeing in building a jet airliner/tanker aircraft to support its B-47 Stratojet and developing B-52 Stratofortress, at the beginning of the 1950s Douglas found its position as the largest manufacturer of airliners under threat.

At the time, Douglas, Lockheed and Convair were all developing piston engined and turboprop airliners prior to any pure jet powered concepts, although Douglas was considering possible layouts for a jet transport as early as 1952, but initially considered the market for such an expensive aircraft to be too small. The success of the privately funded Boeing 367-80 in securing the first order for the USAF jet tanker transport requirement only months after it had been announced in May 1954 caused the other companies to accelerate their programmes.

In fact, Lockheed had won the competition with its L-193 airliner design, but since the Boeing KC-135 Stratotanker development of the 367-80 was to be available two years earlier, 250 were ordered as an interim solution. The USAF realised supporting two tanker transports would be prohibitively expensive, so the order for the L-193 was eventually cancelled. As a result, 803 Boeing KC-135s and 1010 of its airliner derivative the 707 were to be built; Boeing dominating the market for many years.

In the face of this commanding lead, a Douglas team headed by Arthur E. Raymond and Ed Burton produced a swept wing four engined design not unlike the Boeing rival, announcing the new aircraft as the DC-8 in July 1955. In designing the DC-8, Douglas had realised one important fact. In 1952, tourist class fares had been introduced on to the lucrative North Atlantic routes for the first time, essentially the beginning of relatively affordable air travel.

As a result, the DC-8 was designed to be able to accommodate six abreast seating to take full advantage of the demand for economy class travel. There would be four initial versions, the DC-8-10 powered by the 13,500lb (6124kg) thrust Pratt & Whitney JT3C-6 for domestic routes, the DC-8-20 powered by the 15,800lb (7167kg) thrust Pratt & Whitney JT4A-3 to allow higher all up weights and better short field performance to be flown on domestic routes, the DC-8-30 which had the same engines as the -20 but with a one third increase in fuel capacity and a stronger fuselage and undercarriage for intercontinental routes, and the DC-8-40, which was a -30 with the 17,500lb (7938kg) thrust Rolls-Royce Conway. The airlines responded favourably to the design, but still remained reticent about buying expensive new jet aircraft.

However, that changed in September 1955 when Pan American Airways signed an order for 25 DC-8-30s to supplement the 20 Boeing 707-120s it had also ordered, the two groundbreaking orders being made public on October 13, 1955. The Pan Am order meant its competitors had to follow suit, and by the end of the year Douglas had 98 orders for the DC-8 from North American, European and Asian airlines.

The aircraft was to remain in production from 1958 to 1972 in a wide variety of passenger, freighter, stretched and improved versions, including the -61 of 1966 which was stretched by a remarkable 440in (11.2m) to produce a medium range high-capacity airliner for up to 259 passengers.

Improved versions re-engined with 22,000lb (9979kg) thrust CFM56-2 turbofans were still being modified from existing aircraft as late as 1988. Like many other airliners, as they were replaced by more modern types, many were converted as freighters, the US Navy even purchasing a former United Airlines DC-8F freighter as an electronic warfare training platform, the sole Douglas EC-24A. Altogether 556 DC-8s of all its many versions were built, being used by the airlines of 54 nations and the air forces of eight more, a remarkable success considering the head start Boeing had with the 707.

In 2013, 13 were still in service with five cargo airlines and three government agencies. One remarkable record must be mentioned regarding a DC-8-53, c/n 45608, N9608Z. On August 21, 1961, it was flown from Edwards Air Force Base to conduct a test of a new wing leading edge design, the aim being to collect handling and airflow data. At 41,000ft (12,497m) the

The Douglas DC-8-61 featured a fuselage stretched by an incredible 440 inches (11.2m) to produce a medium range high-capacity airliner for up to 259 passengers, first flying on March 14, 1966. **San Diego Air and Space Museum**

United Airlines was the largest operator of the DC-8, purchasing 116 of the type as both airliners and cargo aircraft. This is one of their DC-8-73s, a -63 re-engined with the CFM-56 turbofan. 110 DC-8s were modified to become 70 series aircraft between 1982 and 1988. **San Diego Air and Space Museum**

aircraft was placed in a controlled shallow dive by Captain William Magruder, during which it reached and maintained Mach 1.012 for 16 seconds, the first civilian jet and the first airliner to fly supersonically. Interestingly, the chase plane on this flight was a Lockheed F-104 Starfighter flown by Charles E. Yeager, the first man to break the sound barrier.

The success of the DC-8 and the need for a short haul jet airliner to complement it gave rise to a Douglas design study in 1962. The DC-8 and Boeing 707 were fulfilling the long-range market, and the Boeing 727 had successfully entered the medium haul market, but there was a gap in bringing the speed, economics and reliability of jet aircraft to the short range or feeder routes as they were known. To best meet the needs of the local and regional airlines, Douglas designed a small, swept wing, T-tail airliner with the engines mounted on the rear of the fuselage to avoid ingesting debris from runways and aprons at the smaller airports.

Many features were deliberately built into the design to meet the needs peculiar to this type of operation. Large freight holds were incorporated into the fuselage to enable cargo to be carried as well as passenger baggage and mail. An auxiliary power unit and stairs were built in to allow operation at airports with minimum support equipment. Finally, because the target airlines often flew several sectors between airports, the aircraft was capable of landing at high all up weights to avoid needing to constantly refuel.

Douglas announced the new aircraft, the DC-9, on April 8, 1963, receiving their first order from Delta Air Lines in May. The first flight took place on February 25, 1965, the type entering commercial service on December 8 that year powered by the Pratt & Whitney JT8D. Like its larger stablemate, the DC-9 was to be produced in a plethora of stretched and modified versions, 976 airliners being built between 1965 and 1982.

Additionally, 23 Douglas C-9A Nightingale military aeromedical evacuation aircraft, 24 C-9B Skytrain II military transports and three VC-9C VIP transports were supplied to the USAF, US

The first Douglas DC-9-10 airliner, N9DC, makes its first flight from Long Beach on February 25, 1965, in front of a large crowd of company employees. **San Diego Air and Space Museum**

Navy and Marine Corps between 1968 and 1973, all based on the DC-9. Five more C-9Bs converted form passenger DC-9s were also supplied to the US Navy, one more went to NASA for reduced gravity parabolic flights and two C-9Ks were supplied to the Kuwait Air Force.

After the merger with McDonnell in April 1967, a new model, designated the MD-80, a stretched DC-9 with more powerful JT8D-200 series engines and an electronic flight instrument system or 'glass cockpit' was developed. The first flight took place on October 19, 1979, and entered service with Swissair in September the following year. A total of 1191 MD-80s in a range of five major versions were built between 1979 and 1999, and were followed by the MD-90 series.

Powered by a pair of the 25,000lb (11,340kg) thrust IAE V2525-D5 turbofan, which improved the fuel efficiency of the aircraft tremendously, the MD-90 design studies began in 1983. Launched on November 14, 1989, Delta Air Lines was the first customer with an order for 50 MD-90s, the first flight taking place on February 22, 1993.

The MD-90 was produced in two major versions, the -30 and the -30ER for extended range. Two more sub types were also built, a single increased gross weight aircraft and two 'Trunkliners' produced under licence in China.

Altogether 117 MD-90s were produced between 1993 and 2000, like all of the DC-8 and DC-9 derivatives these were built at the extended Douglas Long Beach plant with the exception of the two Chinese examples built in Shanghai. One more model, the MD-95 was proposed in 1993, a shorter and smaller version, more like the original DC-9-30 and aimed at the same market. The Rolls-Royce BR715 turbofan was chosen to power the MD-95 in two versions for a standard and high gross weight variant of the aircraft, the first flight taking place on September 2, 1998.

However, in August 1997, McDonnell Douglas had merged with Boeing, so the MD-95 was rebranded as the Boeing 717. Although initial orders were slow in coming, the reliability of the aircraft and its economic operation attracted attention and a steady stream of aircraft were supplied all over the world, 156 717s being built between 1998 and 2006. Production ended due to the advent of more modern regional jets, but many of the tough airliners continue in service today. A census in 2013 showed that 63 DC-9s, 511 MD-80s, 72 MD-90s and 148 717s were still in service and likely to remain so for many more years.

NAVAL AIRCRAFT

The Douglas Devastator torpedo bomber had proved to be obsolete by the time the Second World War started, the ➤

The later stretched forms of the DC-9 design are elegant aircraft and many are still in service. This is an MD-81 of SAS taking off from Heathrow in August 2007. **Adrian Pingstone**

The size of the Skyraider is apparent in this mixed force of F4U Corsairs and AD-4 Skyraiders from the carrier USS Boxer (CV 21) pictured in flight off Korea on August 27, 1951. **National Museum of Naval Aviation**

replacement two seat XSB2D-1 and single seat XBTD-1 had been cancelled after only a few had been delivered.

The US Navy had changed the multi-crew BT requirement to a single seat torpedo, bomber and attack aircraft in 1943 in the light of hard-won combat experience.

The Douglas XBTD Destroyer suffered from having been originally a two-seat aircraft, especially as Curtiss, Kaiser-Fleetwings and Martin were all putting forward aircraft which were single crew from the outset. At the beginning of July 1944, Douglas chief engineer Ed Heinemann, chief designer Leo Devlin and chief aerodynamicist Gene Root were all in Washington to discuss the XBTD with the US Navy, only to be told that the programme was cancelled.

Rather than lose their position as a prime supplier of naval aircraft, the team returned to their hotel and overnight drew up an entirely new design, a large, tailwheel, single seat, lightweight but armoured, single piston engined machine. The Navy's Bureau of Aeronautics was impressed with the performance estimates, and on the understanding that the prototype would be ready to compete with the other three manufacturers, on July 6 the Navy ordered 15 of what was known as the XBT2D-1 by amending the existing XBTD contract.

After an astounding effort by the El Segundo Division, the prototype made its first flight on March 18, 1945. Initially the first four of the new aircraft were powered by the 2300hp Wright R-3350-8 Duplex Cyclone, which would be upgraded to the 2500 then 2700hp versions during the aircraft's career.

Fast, strong, powerful and a delight to fly, the new aircraft was redesignated AD-1 in December 1946, later becoming the A-1, and named Skyraider. This was the birth of a legend and suffice to say that 3180 Skyraiders were built between 1945 and February 1957, seeing combat in the Korean War with the US Navy and Marine Corps, as well as with the USAF in the Vietnam War.

The Skyraider was armed with either two or four 20mm M2 cannon in the wings depending on the version. It was able to carry a huge range or ordnance on its 15 external pylons under the fuselage and wings, up to 8000lb (3629kg), the equivalent of two Boeing B-17s. Its range was equally prodigious, up to 1316 miles (2118km), or able to loiter for up to 10 hours over its target area. The flexibility of the design was apparent in the large number of versions produced, among which were two, three and four seat models for day and night attack, electronic counter measures and airborne early warning (AEW) aircraft fitted with the APS-20 radar in a bulbous radome under the fuselage.

The AEW versions were also used by the Royal Navy, other versions of the Skyraider being used by nine other countries including France and Vietnam. The US forces retired their last Skyraiders in 1972, but several ex-French Air Force aircraft were to continue operation with the air forces of Chad and Gabon until 1984 and 1985 respectively. Over 3000 built and nearly 40 years in service – not bad for a night's work in a hotel.

Fleet defence, particularly at night, was a concern of the US Navy in the closing stages of the Second World War. In late 1945, four companies were approached with a requirement for the world's first jet powered night fighter, with Douglas being awarded a contract on April 3, 1946, for three prototypes of what would become the F3D Skyknight. The El Segundo division team under Ed Heinemann had a number of conflicting problems, the size and weight of airborne radars of the time, especially those of sufficient power to detect targets at the required range of 125 miles (201km), meant the aircraft would have to be large for a fighter. The low power of the early jet engines meant a twin engined aircraft would be necessary to achieve a reasonable performance.

The eventual design was a portly aircraft, the two seat side by side cockpit and the twin jets low mounted on the fuselage, when combined with the large nose radome for the Westinghouse APQ-35 radar all resulted in a wide fuselage. A straight wing was chosen as it was not considered that high speed and manoeuvrability were the prime requirements, long loiter time and steady handling were. The first prototype flew on March 23, 1948, powered by two 3000lb (1361kg) thrust Westinghouse J34-WE-24 turbojets, which would rise to 3600lb (1633kg) as the aircraft and engine developed. Altogether, 265 F3Ds were built, production ending exactly four years after the first flight on March 23, 1952.

Initially armed with four 20mm M2 cannon, the Skyknight would be used to develop the AIM-7 Sparrow missile with later versions able to carry four of the missiles on pylons under the wings. It could also be armed with air-to-air unguided rockets and bombs for a limited ground-attack role. The night fighters were to see combat over Korea and in the electronic countermeasures role over Vietnam, the last mission being flown in 1969, by which time the aircraft had been redesignated the F-10. By then, the Skyknight had been largely relegated to secondary roles such as training radar operators and as a radar and systems testbed.

All of the aircraft were retired in 1970, except for three which were loaned to Raytheon as radar testbeds, the last two being retired in the early 1980s. An enlarged three seat version of the design known as the F6D Missileer was proposed in 1959 to carry the large AAM-N-10 Eagle missile. The cancellation of this project in 1960 would lead to the development of the General Dynamics F-111B as a long-range missile armed fleet defender, which in turn would be cancelled and replaced by the Grumman F-14 Tomcat and lead to the requirement for the F-18 Hornet as the complementary lightweight strike fighter to the big Grumman design.

SUPERSONIC SKYRAY

The next Ed Heinemann led design was one of the most unusual jet fighters ever built. In 1947, influenced by German research data, particularly that of Alexander Lippisch, the US Navy issued a requirement for an interceptor fighter that could reach

A pair of Douglas EA-1F Skyraiders of Carrier Airborne Early Warning Squadron (VAW) 13 pictured in 1966. The EA-1F was a four seat electronic countermeasures version of the attack aircraft. **National Museum**

bombers flying at 40,000ft (12,190m) in under five minutes and utilised a delta wing along the lines of Lippisch's concepts. It was believed that this type of wing offered the necessary high rate of climb and maximum speed the fighter would require.

The El Segundo Division of Douglas responded with the XF4D, Heinemann working with C. S. Kennedy to produce the design around the new afterburning Westinghouse XJ40 turbojet, with which engine it was estimated the fighter would exceed Mach 1 in level flight. Armed with four 20mm Colt Mk.12 cannons in the wings and capable of carrying rocket pods and the AIM-9 Sidewinder missile, a contract was issued on December 16, 1948, to build two prototypes as the XF4D-1 Skyray.

Problems with the XJ40 engine meant the prototype Skyray first flew on January 23, 1951, powered by a 5000lb (2268kg) thrust Allison J35-A-17 turbojet. The low power limited testing, early flights exploring the handling rather than the performance. The second aircraft was fitted with the same engine until the afterburning 11,600lb (5262kg) thrust XJ40-WE-8 was ready, after which the second prototype captured the world absolute speed record on October 3, 1953, at 752.944mph (1211.487kph), the first carrier-based aircraft to hold the record.

The troublesome J40 engine programme was cancelled, but Douglas had designed the fuselage to take a range of engines from the beginning, so it was replaced with the Pratt & Whitney J57, the developed models of which produced 16,000lb (7258kg) of thrust with afterburner. After some air intake and duct modifications required by the new engine, testing proved the high performance of the fighter when the first production Skyray exceeded Mach 1 in level flight on its first flight.

The aircraft entered service with the US Navy on April 16, 1956, and with the US Marine Corps less than a year later, its excellent performance being used to set yet more records. On May 22 and 23, 1958, Major Edward LeFaivre set no fewer than five world time to height records,

The Douglas F4D Skyray production line at El Segundo in 1957. **National Museum of Naval Aviation**

culminating in reaching 49,212.5ft (15,000m) in just two minutes, 36.05 seconds. The last of 419 production Skyrays was delivered on December 22, 1958, the aircraft being redesignated the F-6A in 1962.

The fact that it was a single purpose aircraft limited the Skyray's service life, as the US Navy requirements had changed to multi-role aircraft. The last operational Skyrays were retired in 1964, but NASA used four Skyrays for research flights until 1969. One more version of the Skyray was developed, with a stretched fuselage, larger fin and thinner wing among many other refinements; in fact so different was the development that it received a new designation and name, the F5D Skylancer. Only four were built, first flying on April 26, 1956, but the project was cancelled in favour of the Vought F-8 Crusader.

The Skylancers were used in flight test programmes by the US Navy and Marine Corps until 1961, after which two went to NASA as 212 and 213, later renumbered 708 and 802. During its career, 212 was fitted with an ogival wing as part of the American supersonic transport programme, the two Skylancers not retiring until 1970, flying in support of a wide range of NASA programmes.

NUCLEAR SKYWARRIOR

Like the Skyray, the next Douglas naval design was intended to use the J40 turbojet, and like the fighter, this was replaced in the production aircraft by the J57, in this case a non-afterburning example producing 12,400lb (5625kg) of thrust with water injection in its developed form. The aircraft began with a US Navy Request For Proposals (RFP) in 1947 for nuclear bomber with a payload of 10,000lb (4536kg), a range of 4000 nautical miles (7408km) but with a maximum weight not to exceed 100,000lb (45,359kg) or the catapults of even the planned super carriers of the time would not be able to launch it.

The large bomb bay for the nuclear weapons had to be accessible from the crew compartment as the early nuclear devices had to be armed in flight. In response, Douglas project engineer Harry Nichols, working under Ed Heinemann and Leo Devlin at El Segundo, produced a remarkable and long-lived design, the A3D, later A-3 Skywarrior. The 72ft 4in (23.27m) span swept wing was mounted high on the fuselage to clear the bomb bay, which meant the twin engines could be mounted under the wing. The crew of three were housed in a cockpit forward of the bomb bay. ➤

The USAF also used the prodigious load carrying capability of the A-1 Skyraider during the Vietnam War in the close air support and combat search and rescue support roles. This is A-1H, 52-139639, named 'Miss Nordeen' and flown by the wing commander of the 22 Special Operations Squadron, 56th Special Operations Wing, based at Nahkon Phanom. **USAF**

Although similar in appearance to the Navy's Skywarrior, the USAF's Douglas B-66B Destroyer was a very different airframe. **USAF**

Douglas F4D-1 Skyrays lined up at Marine Corps Air Station (MCAS) Yuma, Arizona. The aircraft are of squadrons participating in the Naval Air Weapons Meet. **National Museum of Naval Aviation**

Douglas A4D-2 Skyhawks of Attack Squadron (VA) 12 from the carrier USS Essex (CVA 9) on the flight line at Marine Corps Auxiliary Air Station (MCAS) Yuma, Arizona, during participation in a weapons meet on December 3, 1959. **National Museum of Naval Aviation**

The necessarily capacious fuselage also housed large fuel tanks, with more in the inner wings to provide the range. The tailplane was mounted on the fin to clear the engine exhaust, and the simple tricycle undercarriage retracted into the fuselage. The entire aircraft and its systems weighed only 68,000lb (30,844kg), which meant it would be able to operate from the existing Midway class carriers, an astounding achievement for such a large long-ranged bomber. Two thirds the weight of its nearest rival, the US Navy ordered three prototypes on March 31, 1949.

The first one flew on October 28, 1952, at Edwards Air Force Base, powered by the J40 turbojet. The low power then cancellation of this engine led to its replacement by the J57 on the first 50 production aircraft, this delay meant the Skywarrior did not enter service with VAH-1 at NAS Jacksonville in Florida until March 31, 1956.

Its long range and high speed was demonstrated in July by an unrefuelled flight from Honolulu to Albuquerque in New Mexico, 3200 miles (5150km) in just five hours and 40 minutes, an average speed of 565mph (909kph). The capacious Skywarrior was also to be developed into electronic warfare, reconnaissance, tanker and trainer versions, five becoming VIP transports with a cabin in place of the bomb bay.

The A3D was redesignated as the A-3 in 1961, and was used on bombing missions over Vietnam for the first time in 1965. They were quickly supplanted by other naval types in this role but continued to serve in their many supporting capacities, taking part in the Gulf War of 1991 as electronic reconnaissance platforms just before their retirement on September 27 that year. Several of the 282 US Navy Skywarriors ended up as testbeds for a variety of systems, the last being retired by Raytheon on June 30, 2011, when it was flown to NAS Pensacola to join the ranks of the National Museum of Naval Aviation.

The high performance and capacity of the design attracted the attention of the USAF, who wanted it as a light bomber to replace the Douglas A-26 Invader and as an all-weather and night reconnaissance aircraft. The conversion of the naval aircraft was undertaken at the Long Beach Division, headed by John C. Buckwalter who began work in 1952. What was supposed to be a simply de-navalised variant became almost a new design, with a modified wing, lighter undercarriage, revised cockpit layout with a new canopy and finally the replacement of the J57 engines with the 10,200lb (4627kg) thrust Allison J71-A-11 turbojet.

The USAF version also differed from the Navy's in having a tail turret with twin 20mm cannon and ejection seats, the naval version only having an escape chute to save weight. The prototype RB-66A first flew on June 29, 1954, the first of five pre-production trials aircraft. Eventually 294 were to be built before production ended in June 1958. Of these aircraft, 72 were built as the B-66B Destroyer, the bomber variant, as opposed to 145 of the RB-66B reconnaissance version. Two other versions, 36 of the RB-66C electronic reconnaissance platform and 36 of the WB-66D weather reconnaissance aircraft were also built, the latter being the last B-66 airframes to roll off the production lines.

Two WB-66Ds were modified to become the X-21s by Northrop to test the Laminar Flow Control system, where boundary layer air suction was used in place of conventional control surfaces. A much larger wing was fitted and the engines were moved to the rear fuselage sides, the first X-21 flying on April 18, 1963. Although successful and showing a great reduction in drag, practical maintenance difficulties meant the experiments were dropped. A number of the B-66s and RB-66s were modified to become EB-66C and E electronic warfare and reconnaissance versions, being extensively used over Vietnam. The type never saw combat in the original bomber role, the last EB-66Cs and Es were retired in 1975.

The last Douglas naval design before the merger with McDonnell was another famous and enduring aircraft, the A4D, later A-4 Skyhawk. Like Welko Gasich at Northrop who was working on the first designs that became the F-5, Ed Heinemann was increasingly concerned over the weight and complexity of fighter aircraft, so began a private venture design to produce a light fighter for the US Navy which was presented to it in early January 1952.

Since a number of fighters were under development, the Bureau of Aeronautics suggested the lightweight concept might better fulfil the requirement for a jet powered carrier-based attack aircraft.

This requirement called for a 500mph (805kph) single seat aircraft capable of carrying at least 2000lb (907kg) of weapons for a range of 345 miles (555km) and was aimed at producing an aircraft capable of conducting nuclear strikes. The aircraft was not to exceed 30,000lb (13,608kg) maximum gross weight, a challenging specification for the day.

Douglas A3D Skywarriors during the Heavy Attack Wing (HATWING) 1 Bombing Derby at Naval Air Station (NAS) Sanford, Florida on December 23, 1958. **National Museum of Naval Aviation**

A Douglas A-4E Skyhawk of Marine Attack Squadron (VMA) 131 assigned to the Marine Air Reserve Training Detachment (MARTD) at Naval Air Station (NAS) Willow Grove, Pennsylvania drops bombs during a training mission. **National Museum of Naval Aviation**

HEINEMANN'S HOTROD

Just two weeks later Heinemann was back at the bureau with a design which was less than half the specified weight fully loaded, 100mph faster and had a range 115 miles (185km) farther than the requirement. It was also so compact at 27ft 6in (8.38m) wingspan that it would not require wing folding for stowage on carriers. The estimated weight and performance of the small, single engined tailed delta design met with some scepticism, but on June 21, 1952, Douglas received a contract for one prototype XA4D-1 and a static test airframe.

Every effort was made to reduce the weight of the aircraft an increase its structural strength. Since the wing did not need to fold, the undercarriage legs retracted into external fairings under the wing, only the wheel being housed in a recess in the wing itself. This meant the wing spar could be one contiguous piece from wing tip to wing tip, far lighter and stronger than it would have been possible to make it with any breaks. Although problems with the milling machine that made the spars caused some delay to the project, this feature was to result in an amazingly strong aircraft.

The engine chosen for the Skyhawk was the Wright J65 turbojet, a licence-built copy of the Armstrong Siddeley Sapphire which would produce 8400lb (3810kg) of thrust in the A-4C version of the Skyhawk, before it was replaced in the A-4E by the Pratt & Whitney J52 which would eventually produce 11,200lb (5080kg) of thrust during its development.

One pylon was fitted under each wing along with a centreline pylon under the fuselage for the carriage of weapons and external fuel tanks, while a Colt Mk 12 20mm cannon was fitted in each wing root.

The prototype XA4D-1 flew for the first time on June 22, 1954, the flight test programme resulting in three changes to the design. The wing was fitted with vortex generators in two rows on the upper surface towards the tip to eliminate wing buffet and the tail cone was modified to smooth the airflow at the engine exhaust. The last modification, a single skin rudder with external ribs, designed to stop rudder vibrations, was introduced on the second version of the Skyhawk on the production line.

The first A4D-1s, later redesignated A-4As, were delivered to VA-72 of the US Navy on September 26, 1956, its small size and light weight meaning the Skyhawk could operate from even the smaller, older carriers. These were the first of 3960 built up to 1979, a tremendous success for Douglas. The design was to acquire two more underwing pylons and grow various bulges, particularly above the centre fuselage, as additional fuel and avionics turned the day attack aircraft into a true all weather strike platform through 25 single seat versions in its long career.

The Skyhawk was to be a major part of US Navy and Marine Corps operations in the Vietnam War, beginning in August 1964 after the Gulf of Tonkin incident. Also in 1964, two prototypes of a two-seat advanced jet trainer were ordered as the TA-4E, the first of 11 versions of the two-seat trainer, which retained all of the weapons capabilities of the single seater. The Skyhawk was withdrawn from the US Navy's front line squadrons by the end of 1975 and the US Marine Corps units by 1987, after which they were used by reserve, target tug and the aggressor training units until the last TA-4Js were retired in 2003.

Aside from the US forces, the Skyhawk was purchased by 10 countries, seeing combat use with three, Argentina, Israel and Kuwait. It remains in service with three nations with upgraded avionics and systems in both single seat and two seat versions, serving with the Argentine Air Force, Brazilian Navy and Singapore Air Force.

Eleven ex-Royal New Zealand Air Force aircraft are operated by Draken International, a company that supplies adversary training facilities to the US Forces.

These successes with such a wide range of aircraft proved to be a double-edged sword for Douglas, and by 1966 some serious problems had arisen. The demand for the DC-8, DC-9 and A-4 meant that additional production facilities needed to be found, the old El Segundo Division plant had been closed in 1962 after the last A-3 had been built and A-4 production had transferred to the Long Beach facility. Shortages and other problems were increased by the US involvement in the Vietnam War, exacerbated by rising costs, supply difficulties and a shortage of trained workers.

The failure of Douglas to compete with Lockheed in the USAF competition that led to the C-5 Galaxy large transport aircraft and the lack of interest from airlines in their rival to the Boeing 747 were further blows to the company, which, alongside the rising costs of the development of their DC-10 widebody airliner, caused Douglas to attempt to raise an additional $50 million of equity capital against its substantial order book to fund the much needed new production facilities.

However, advice from the Wall Street firm of Lazard Frères suggested a merger would be a more satisfactory answer to the company's woes and several offers were made from other aircraft companies. On January 13, 1967, the offer from McDonnell was unanimously accepted and approved by the US Government. The Douglas Aircraft Company ceased to be, and the McDonnell Douglas Corporation was born.

■ Words: *Tim Callaway*

A Curtiss JN-4 'Jenny', the type that McDonnell took his first flight in.
Florida State Archive

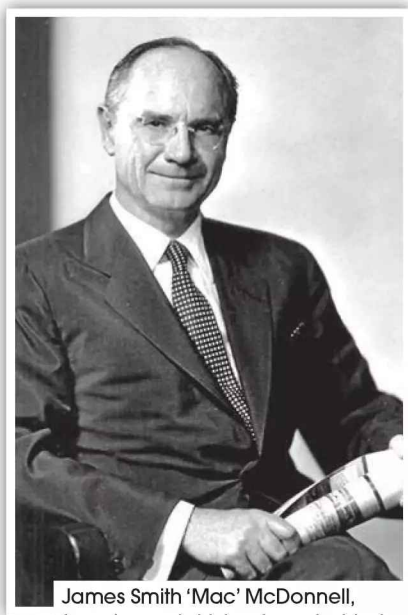
The F/A-18 partners

McDonnell to McDonnell Douglas, Doodlebug to the F-18 Part two

The history of the McDonnell Aircraft Company is the story of one man, James Smith McDonnell. His story has many interesting parallels with that of Donald Douglas, not least of which was the fact that both men were of Scottish ancestry. like Douglas, McDonnell was to produce some remarkable naval and military aircraft, their combined experience making a natural merger of their companies.

As already noted in the previous article, the shareholders and board of the Douglas Aircraft Company had accepted the bid for a merger with McDonnell on January 13, 1967, and, following the approval of the US Government, as both companies were major suppliers of the US military, the merger itself took place on April 28, 1967. McDonnell was, like Douglas, a company founded and driven by the vision of one man, in this case James Smith 'Mac' McDonnell, his nickname forming that of his company which was often referred to as 'MacAir'. McDonnell was born in Denver, Colorado, on April 9, 1899, the fourth son of James McDonnell Sr, a Scottish cotton grower who had settled in Little Rock, Arkansas. Here he grew up, attending Little Rock High School from where he graduated in 1917.

As a child, the young McDonnell was a reserved and quiet personality, but showed from an early age the drive and energy that would serve him so well in later life. To earn pocket money, he would get up early and deliver the local paper on horseback before going to school. With the US entry into the First World War, McDonnell joined the US Army where he served as a private for a short time before attending Princeton University in New Jersey.



James Smith 'Mac' McDonnell, founder and driving force behind the McDonnell Aircraft Corporation.
National Air and Space Museum

McDonnell was chief designer of the Hamilton Metalplane Company in 1926, his first design being the single engined H-18, a mid-wing open cockpit mailplane. **Hamilton**

The Hamilton H-18 was followed by the H-45 with a crew of two and six passenger seats. **Hamilton**

McDonnell assisted in the design of the Ford Trimotor while working for the Stout Metal Airplane Company of Dearborn, Michigan, a division of the Ford Motor Company. **Constance Redgrave**

Here, he studied physics while continuing his military training in the Reserve Officers Training Corps (ROTC) and developed two abiding interests, politics and flying. The second interest began in an unusual way.

Typically punctual, McDonnell had arrived in Princeton a few days early to begin his freshman year and settle himself in. The climate being somewhat brisker than Arkansas, he realised he required a winter coat, so took the trolley car into Trenton in order to purchase one.

Along his journey, he saw a Curtiss JN-4 Jenny sitting in a field by the road, alongside which was a sign saying "Once in a lifetime joy rides – $10". This was precisely the sum in his pockets, so he jumped from the trolley and handed his winter coat money to the pilot. That short trip really started something.

EARLY CAREER

On graduating from Princeton with a Bachelor of Science (Physics) in 1921, McDonnell immediately enrolled in the famous Massachusetts Institute of Technology (MIT) to study for a master's degree in aeronautical engineering.

He remained in the ROTC during his studies, attending regular training courses at Mitchell Field. Here, he passed the medical examination for the Army Air Service and completed the majority of the ground school then required to be a military pilot. In August 1923, with his studies complete, McDonnell was commissioned as a second lieutenant in the Army Air Service and called to active service at Brooks Field in Texas for a year of pilot training.

Here, he made his first solo flight and his first parachute jump, earning his wings and carrying out a number of 'odd jobs' as a pilot. Released from military service in 1924, he began a series of jobs with aircraft companies, the first being as a draughtsman with the Huff-Daland Airplane Company in Ogdensburg, New York. After a few months in the drawing shop, he moved to the Consolidated Aircraft Company in Buffalo as a stress analyst.

Receiving his master's from MIT in 1925, McDonnell was hired by Tom Towle as assistant chief engineer at the Stout Metal Airplane Company of Dearborn, Michigan, which had just become a division of the Ford Motor Company. Here he helped redesign the underpowered Stout 3-AT three engined airliner, which would become famous as the all-metal Ford 4-AT Trimotor.

The promotion of the 4-AT by Ford as a supremely safe aircraft by dint of its metal airframe led others to begin building metal aircraft, including Thomas Foster Hamilton, who had formed the Hamilton Aero Manufacturing Company of Milwaukee in 1919, manufacturing propellers. In the light of the development of the 4-AT, the Hamilton Metalplane Company was founded, Hamilton hiring McDonnell as chief designer in 1926. His initial design of the single engined H-18, a mid-wing open cockpit mailplane, won a number of awards including the Spokane Air Races of 1927. This was followed by the high wing H-45 and H-47 designs, both with two-seat enclosed cockpits and six-seat passenger cabins. The major difference between the two aircraft was that the H-45 was powered by the 450hp Pratt & Whitney Wasp and the H-47 by the 525hp Hornet from the same company. Some 46 of both types were built, operating on both wheels and floats with six airlines as passenger, cargo or mailplanes. Later, several were used by the Peruvian Air Force during the Columbia-Peru War in 1932. ➤

J. S. McDonnell Jr. and Associates' only aircraft, the Doodlebug, designed for the competition organised by the Daniel Guggenheim Fund for the Promotion of Aeronautics. **NASA**

After moving to Martin, McDonnell worked on the improvements to the B-10 and B-12 bombers for the US Army Air Corps. **USAF**

While working for the Great Lakes Aircraft Corporation, McDonnell helped design the unusual XSG amphibious observation aircraft for the US Navy. **US Navy**

McDonnell's last design for Martin, the 167 Maryland bomber, used by the British, French and South African Air Forces in the Second World War. **USAF**

The first company formed by James McDonnell came about because of a prize offered by the Daniel Guggenheim Fund for the Promotion of Aeronautics on April 20, 1927. This was a competition to design a training aircraft offering "a real advance in the safety of flying". McDonnell and two friends, engineers Constantine Zakhartchenko and James Cowling, were intrigued by the concept, prevented only by a lack of funds from entering the contest.

However, in 1928, McDonnell founded J. S. McDonnell Jr. and Associates with the two other engineers in order to build an entry for the $100,000 prize. Hamilton assisted in this venture by providing hangar space and other facilities, even though McDonnell's involvement in the project led to his resignation.

The aircraft, known as the Doodlebug, was a low wing single engined monoplane with two open cockpits. A lack of funds slowed the production process to the point it missed the competition deadline of October 21, 1929. The design showed such promise that an extension was granted, but during a test flight on November 21, 1929, the tailplane failed, folding in flight. McDonnell, who was flying it, fought the crippled aircraft all the way to the ground in an attempt to save it, making a hard forced landing that badly damaged both the Doodlebug and McDonnell's back.

Typical of the phlegmatic engineer, McDonnell later commented that he was "too much of a Scotsman to use my parachute"! A second extension was granted and the aircraft was repaired, but on the way to New York for the contest, the engine failed and it was damaged again in the ensuing forced landing.

The competition was won by the Curtiss Tanager, but McDonnell took the Doodlebug on a demonstration tour of air shows to seek private buyers and demonstrate the fine flying characteristics of his creation. At the time, the US was in the grip of the Great Depression after the stock market crash of October 1929, so no customers were forthcoming, bad luck and bad timing ended McDonnell's dream of his own aircraft company prematurely.

McDonnell had joined the Airtransport Engineering Corporation of Chicago, where he worked as a consultant in the first two lean years after the crash, his aim being to develop a commercially viable version of the Doodlebug. Again, the market was non-existent, so in 1931, McDonnell sold the now reliable monoplane to the National Advisory Committee for Aeronautics (NACA, later to become NASA), who used it as a test bed for leading edge slats and other technologies.

That same year, he went to work for the Great Lakes Aircraft Corporation in Cleveland as an engineer and test pilot, working on the biplane 2T or Sport Trainer and the XSG amphibious observation aircraft for the US Navy among other types. In another parallel with the life of Donald Douglas, in early 1933 James McDonnell was offered a post with the Glenn L. Martin Company, by that time based in Baltimore, Maryland. Here he quickly rose to the position of chief engineer of landplanes, again like Douglas, who had held the position between 1915 and 1920.

Strangely, McDonnell was also to stay with Martin for five years. During this relatively stable period of his life he not only worked on the development of the B-10 and B-12 bombers for the US Army Air Corps (USMC) and their export variants, he also designed the Martin 167 Maryland bomber which was used by the British, French and South African Air Forces in the Second World War. He also found time for family life, marrying Mary Elizabeth Finney, the daughter of the founder of the American College of Surgeons on June 30, 1934.

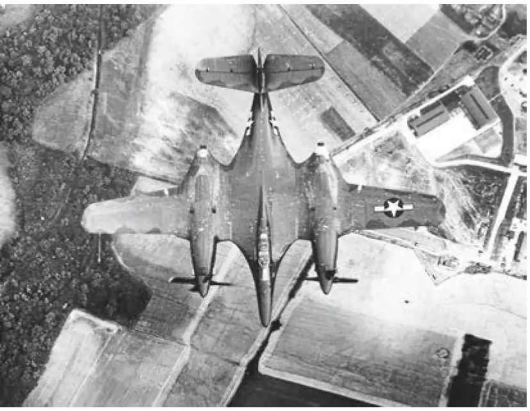
MCDONNELL IS FORMED

Despite the challenges of his job at Martin and his growing family, his two sons being born in 1936 and 1938, McDonnell's career history to this point had gained him an enormous amount of varied experience with one simple aim, to begin his own aircraft company and develop his own ideas.

Again, like Donald Douglas before him, he left Martin towards the end of 1938 and on July 6, 1939, he founded the McDonnell Aircraft Corporation. McDonnell set up an office in the Park Plaza Hotel in St Louis, Missouri, before moving to a second-floor room in the American Airlines building at Lambert Field, later St Louis Airport.

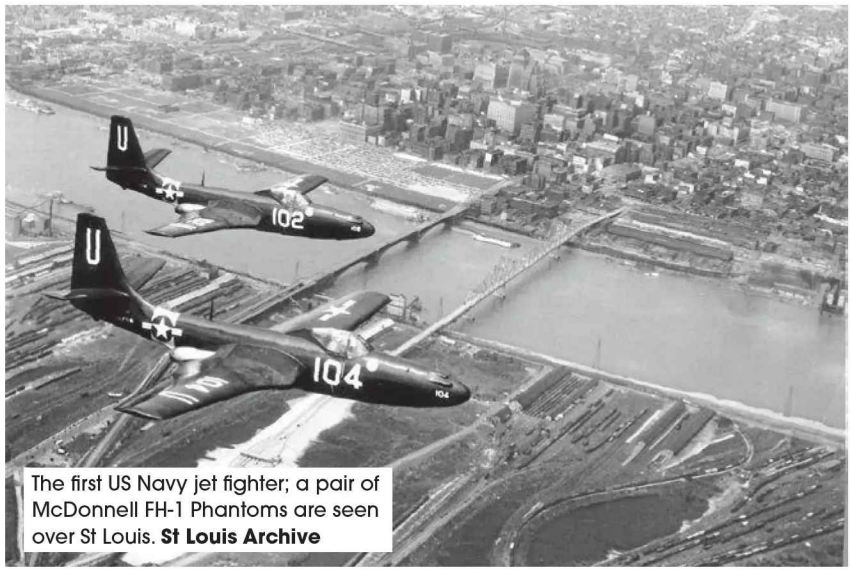
Work began on September 25 and for the next 12 months the company submitted 12 proposals to the USMC and four more to the US Navy. Every one of the proposals met with rejection, but the McDonnell company began to receive subcontract work from other companies as the US aircraft industry began to rapidly expand as the Second World War began in Europe.

During the war years the company was to produce Douglas A-20 and C4 7 parts, Boeing B-29 fuselage sections and complete Fairchild AT-21-MM twin engined trainers,



The McDonnell XP-67 Bat in flight, showing its unusual blended lines. **USAF**

The second McDonnell jet fighter design for the US Navy, the F2H-2 Banshee, here carrying wing tip tanks and under wing HVARs. **Constance Redgrave**



The first US Navy jet fighter; a pair of McDonnell FH-1 Phantoms are seen over St Louis. **St Louis Archive**

The McDonnell F2H-2P Banshee featured an elongated nose to carry a variety of cameras in the photo reconnaissance role. **National Museum of Naval Aviation**

using various rented factories around Lambert Field and a US Government built factory in Memphis, Tennessee. The company also had a number of early successes with its own designs in this time too, responding to the USMC's March 1940 Request For Proposal (RFP) R-40C for a long range, high-speed, high-altitude fighter with its Model I design.

This was rejected, but the company's design ideas showed sufficient promise that McDonnell was awarded a $3000 contact to rework the design in June 1940. The next version, the Model II was similarly rejected, but the reworked Model S-23-A was accepted, the recently redesignated US Army Air Force (USAAF) awarding a contract on October 29, 1941, to develop and build two prototypes of the unusual McDonnell design, now designated the XP-67.

This had an aerofoil section fuselage, fully blended with the wings and faired in engine nacelles in an attempt to reduce drag as far as possible. The unusual form of the aircraft gave rise to its nickname of the Bat, later adopted as the official name.

Powered by a pair of the experimental 1350hp Continental XN-1430-17/19 12-cylinder liquid-cooled engines and General Electric D-23 turbosuperchargers, the engines were to cause many problems, including setting the nacelles on fire during a ground run of the prototype XP-67, 42-11677, on December 8, 1943.

The first flight took place after repairs and further engine tests on January 6, 1944, but this too was cut short by engine problems after only six minutes in the air. The low power and overheating problems of the engines were never to be solved, even though the test flying programme proved positive although showing little performance advantage over existing aircraft. On September 6, the starboard engine caught fire in flight, test pilot E. E. Elliot making a safe landing at Lambert Field, but despite his attempt to park the aircraft so the flames would blow away from the airframe, the fire damaged the fuselage, wing and nacelle. On September 13, the USAAF cancelled the project and work was stopped on the second prototype. However, the ambitious fighter was to lead to McDonnell's first major success.

NAVAL SUCCESS

One of the proposed powerplant upgrades in the development of the XP-67 was the addition of an I-20 turbojet in the rear of each engine nacelle. It was this ambitious aircraft, and the experience the company had with pulsejets in the Katydid drone, that attracted the attention of the US Navy's Bureau of Aeronautics when they began to investigate the possibilities of jet propulsion in 1942.

This was to begin a long and highly successful association between the manufacturer and the service that would produce some remarkable aircraft. In response to the Navy's interest, the first of these designs began with a proposal in January 1943 for a twin engined carrier-based jet fighter. On January 7, the US Navy ordered two prototypes and a static test airframe of the design, intended as a carrier defence fighter and designated XFD-1.

The uncertain and experimental nature of the powerplant led to an eight, six, four and twin engined design all being considered by the head of the design team, Kendall Perkins, before two large engines were selected for simplicity and ease of maintenance. The powerplant also affected the layout of the aircraft in significant ways.

Early turbojets needed short tailpipes to avoid a loss of thrust, so the engines were mounted in the wing roots, each with an individual air intake. A tricycle undercarriage was fitted to avoid the jet exhaust striking the deck of the carrier, which in the US fleet were mostly of wooden construction at that time.

The tailplane was mounted on the fin and given dihedral to keep it out of the jet exhausts, but other than this the fighter was a conventional straight wing design with the cockpit and armament of four .50 cal (12.7mm) machine guns mounted in the forward fuselage. Problems with the development of the Westinghouse WE-19XB-2B turbojet meant that by October 1944, only one had been delivered, so early ground trials were conducted on the power of a single engine, a short hop being made on the runway on January 2, 1945, despite only 1165lb (528kg) of thrust being available.

With the fitting of the second engine, test pilot Woodward Burke took the XFD-1 on its first full flight on January 26, the aircraft proving to be easy to fly. With further testing, the incidence of the tailplane was changed to ➤

Looking surprisingly modern in the later grey and white scheme, this F2H-4 Banshee is on display in the National Museum of Naval Aviation at Pensacola, Florida. **Constance Redgrave**

An Allison J71 powered F3H-2 Demon of VF-31 lands on a carrier. This version could carry the AIM-7 and -9 air-to-air missiles as well as bombs and rockets for ground-attack missions on two fuselage and six wing pylons. **National Museum of Naval Aviation**

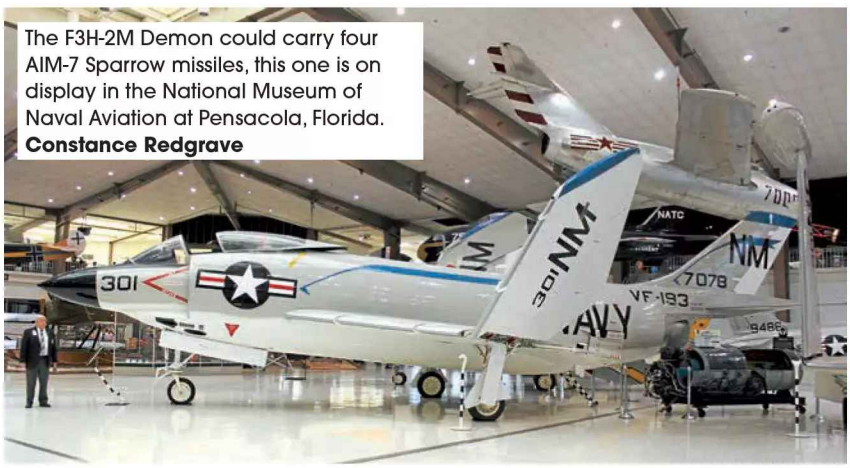
correct a longitudinal instability and the aileron circuit redesigned. With these modifications, the fighter, now named Phantom, became the first US Navy aircraft to exceed 500mph (805kph) in level flight and a production contract for 100 aircraft was issued on March 7.

The first XFD-1, 48235, was lost on November 1 due to an aileron failure which killed Burke. The second aircraft was further modified, and on July 19, 1946, Lieutenant Commander James Davidson made the first take-off and landing of a pure jet aircraft from a US carrier, the trials taking place aboard the USS *Franklin D. Roosevelt* off Norfolk, Virginia.

The end of the Second World War had seen the production order cut to just 30 aircraft, but this was reinstated to 60, the last of which was built in May 1948. The aircraft was also redesignated as the FH-1, the original use of D had been to refer to Douglas, who had not produced aircraft for the US Navy for some time. With Douglas' return to the field, McDonnell was assigned the manufacturer letter H.

The Phantom entered service with VF-17A in August 1947, but by the end of 1949 all the FH-1s had been relegated to reserve and training units, replaced by McDonnell's development of the concept, the F2H Banshee. While short lived, the FH-1 Phantom was to convince the US Navy of the feasibility of jet operations, and secure McDonnell's future as a supplier of naval aircraft.

Outside the McDonnell factory in St Louis, the prototype F-3H-1 Demon shows off its narrow air intakes on the fuselage sides. **McDonnell**



The F3H-2M Demon could carry four AIM-7 Sparrow missiles, this one is on display in the National Museum of Naval Aviation at Pensacola, Florida. **Constance Redgrave**

BANSHEE AND DEMON

Before the production of the FH-1 Phantom had even begun, McDonnell realised that the low power of the early turbojets would quickly be improved upon, so began work on a design to accommodate larger engines. Initially intended to use as many parts of the FH-1 as possible, it quickly became apparent to Herman D. Barkey and his engineering team that the new engines, the required increase in internal fuel and a change in standard armament from four .50 cal machine guns to four 20mm cannons would preclude this, so although similar in appearance to the FH-1, the F2H was an almost an entirely new airframe.

On March 22, 1945, the US Navy ordered three XF2D-1 prototypes, later redesignated XF2H-1s. Initially powered by the 3000lb (1361kg) thrust Westinghouse J34-WE-22 turbojet, nearly twice the thrust of the FH-1's engines, these would eventually develop 3600lb (1633kg) of thrust in the later -38 version of the engine.

Development was slowed by the end of the Second World War, the prototype not flying until January 11, 1947, in the hands of test pilot Robert M. Eldholm. Satisfactory trials meant the F2H-1 replaced the FH-1 on the production line at St Louis in August 1948 only three months after the last Phantom had been built.

The Banshee was to be a major success for McDonnell, with 895 F2Hs being built in eight major variants for the US Navy and Marine Corps and the Royal Canadian Navy before production ended on September 24, 1953.

Aside from the first day fighter version, the Banshee was to be produced as a fighter-bomber, nuclear strike aircraft, radar equipped all weather and night fighter and photographic reconnaissance platform, the fuselage being stretched and the wing modified to better accommodate these roles.

After the first deliveries to VX-3 in August 1948 for service evaluation, the

The F-101C had a strengthened airframe, improved low level bombing systems and other avionics. This particular aircraft was later converted to an RF-101H. **USAF**

The development of the XF-88 into the prototype XF-101 Voodoo XF-101 meant fitting larger intakes and engine bays and moving the tailplane to near the top of the fin to clear the engine exhaust. **USAF**

A McDonnell RF-101C reconnaissance aircraft over Vietnam in May 1967, the type seeing extensive use in this theatre. **USAF**

Two McDonnell F-101B Voodoo fighters of the 18th Fighter-Interceptor Squadron clearly showing just how far the new afterburner of the two-seat fighter extended aft of the engine bay. **USAF**

Banshee was to see combat over Korea, initially in 1951 as an escort fighter, due to its excellent climb rate and high-altitude performance, before later versions were used as fighter-bombers, night fighters and reconnaissance aircraft in this theatre.

Twenty US Navy and seven US Marine Corps units were to operate the aircraft until the advent of swept naval wing aircraft meant the Banshee was relegated to training and reserve units in September 1959, the last being retired in 1961. In Royal Canadian Navy service, 39 F2H-3 Banshees were transferred from US Navy stocks between 1955 and 1958, the last 11 being retired in September 1962.

The US Navy recognised the need for a high-performance carrier-based interceptor to maintain air superiority as early as 1947. An RFP for an interceptor was issued on May 21, 1948, the McDonnell Model 58 being selected from 11 competing designs seven months later and designated F3H. Designed by a team led by Richard Deagen, the programme was accelerated when the MiG-15 was first encountered over Korea in 1950, the production aircraft being ordered before the prototype had even flown.

Test pilot Robert M. Edholm took the first of two prototype XF3H-ls, 125444, into the air at St Louis on August 1, 1951, but problems with the engine delayed testing and development. Like the Douglas F4D Skyray, the F3H was intended to be powered by the Westinghouse J40 turbojet, but this engine never developed the promised power or anything like the required reliability and every aircraft designed to use it was eventually either re-engined or cancelled.

Unlike the Skyray, the F3H, now named Demon, was designed around the J40, so any change of powerplant required significant modification. At the same time as the engine problems became evident; the US Navy also changed the mission requirement to that of all-weather fighter, which necessitated further changes to be made.

Consequently, the first of 58 production F3H-1N Demons did not fly until December 1953. This first batch of aircraft suffered a series of accidents largely due to the engine, three of which were fatal, so were grounded and relegated to ground training use.

The engine problems had prompted project engineer R. J. Baldwin to convince the US Navy to allow the substitution of the Allison J71 afterburning turbojet in November 1952. Two F3H-1Ns were modified as prototypes of the J71 powered F3H-2N on the production line, the wing being increased in size at the same time to cope with the additional weight of the equipment for the all-weather role.

The first J71-powered Demon flew on April 23, 1953, 140 F3H-2Ns were built, armed with four Colt Mk.12 20mm cannons and four AIM-9 Sidewinder missiles on underwing pylons, alongside 80 F3H-2Ms, a development able to carry four AIM-7 Sparrow missiles. The last production version, the F3H-2, could carry the developed versions of the AIM-7 and -9, as well as bombs and rockets for ground-attack missions on two fuselage and six wing pylons.

A total of 239 F3H-2s were produced, making 519 Demons altogether, the final aircraft being delivered on April 8, 1960. Twenty-two US Navy Squadrons were to use the type, first entering service in 1956 and proving reliable and popular with pilots, due in part to the excellent view from the cockpit and docile handling at high altitude and on approach.

The lack of power from the 14,750lb (6690kg) thrust Allison J71 and the increase in weight for the all-weather role limited the Demon to subsonic performance, but it successfully fulfilled the role of fleet defence fighter until it began to be replaced, initially by the Vought F-8 Crusader and finally by the next McDonnell fighter, the superb F-4B Phantom II, in September 1964.

VOODOO REAPPEARS

As listed in the accompanying table, the XF-88 penetration fighter project had been cancelled in 1950, but interest in a long-range fighter continued. In February 1951, the USAF issued a General Operational Requirement (GOR) for a long-range bomber escort, to which McDonnell responded with a larger version of the XF-88 design. This had more powerful engines and three times the fuel load of the original concept, the design team being headed by Edward M. Flesh. ➤

The engineering mockup of the YAH-1, the aircraft that would later become the world famous F-4 Phantom II. Note the single seat cockpit, anhedral wing and flat tailplane. **National Museum of Naval Aviation**

A Royal Canadian Air Force CF-101 B fires an AIR-2 Genie air-to-air rocket. **RCAF**

On December 6, 1959, the second XF4H-1 prototype performed a zoom climb to a world record altitude of 98,557ft (30,040m) as part of Operation Top Flight. Note the early canopy and nose profile for the AN/APG-50 radar. **US Navy**

The USAF evaluated the F4H-1F in 1961 as the F-110A. **USAF**

This was announced as the winner in May, with discussions leading to the adoption of the Pratt & Whitney J57 as the engine of choice for the new fighter, now designated XF-101. This engine required larger intakes and engine bays, while the tailplane was moved to near the top of the fin to clear the engine exhaust.

While these modifications were under way, in January 1953 the requirement for the aircraft was changed to become a tactical fighter, capable of delivering nuclear weapons as well as escorting long-range bombers. The redesign was approved and a contract issued for 29 F-101As on May 29, 1953, no prototypes being required as it was seen as a development of the XF-88, the first production batch would be used for evaluation and testing.

The first flight took place on September 29, 1954, the 15,000lb (6804kg) thrust J57-P-13 turbojets giving the aircraft a maximum speed of Mach 1.52. With the end of the war in Korea and the advent of the B-52, interest from Strategic Air Command in the escort fighter waned, but by then Tactical Air Command had seen the possibilities of the F-101 and testing continued throughout 1955 and 56 to develop and modify the aircraft to the fighter-bomber role.

The improved version began production in November 1956 with an additional 48 F-101As being built. Two of these aircraft were modified as engine testbeds for the more powerful P-55 version of the J57 and the General Electric J79, the former setting a world absolute speed record of 1207.6mph (1943.45kph) on December 12, 1957.

Two more of the aircraft were modified on the production line to become the first YRF-101As, the elongated nose housing four low level cameras, with two more high altitude cameras mounted behind the cockpit in the space formerly occupied by the ammunition bays for the four M39 20mm cannons of the fighter version.

These were the first supersonic reconnaissance aircraft in the USAF inventory, with 35 RF-101As being built after the successful trials of the two modified airframes. The 6.33G limited F-101A proved to be unsuited to the low level strike role, so an improved and strengthened version was produced capable of sustaining 7.33G. The new F-101C had improved low level bombing systems and one of the cannons was frequently removed to accommodate TACAN navigation equipment.

Many of the F-101As were modified in service with these improved avionics. First flying on August 21, 1957, 47 F-101Cs were built for the USAF, followed by 166 RF-101Cs, the camera equipped reconnaissance variant, which were the last single seat Voodoos built with the final aircraft being delivered on March 31, 1959. The RF-101As and Cs were to see extensive use in the Cuban Missile Crisis and the Vietnam War with the USAF, with eight RF-101As being transferred to the Republic of China Air Force in 1959 for use on reconnaissance flights over mainland China from Taiwan until the late 1970s.

Between 1965 and 1966, the F-101A and C were replaced in front line service and a number were modified with cameras in the nose and cannon bays to become reconnaissance aircraft, 29 F-101As being modified as RF-101Gs and 32 F-101Cs becoming RF-101Hs. These were to serve with Air National Guard units until 1972.

While this work was going on, in early 1953 it became apparent that the future interceptor programme that would result in the Convair F-102 Delta Dagger and F-106 Delta Dart would be delayed; the aircraft and associated equipment taking longer in development than foreseen. The F-101B was selected for development as an interim supersonic interceptor in June 1954 and would feature a major redesign of the airframe.

Firstly, the entire forward fuselage was altered to accommodate a tandem two-seat cockpit and the Hughes MG-13 fire control radar, the cannons were deleted and replaced with a weapons bay that could accommodate four AIM-4 Falcon missiles on a rotating palette. The palette could also accommodate two AIR-2 Genie nuclear armed air-to-air rockets externally.

The F-101B was powered by the P-55 version of the J57 which produced 16,000lb (7258kg) of thrust, the longer afterburner protruding from the rear

The first US Navy Squadron to operate the Phantom II wasVF-74 aboard the USS Forrestal, who took delivery of an initial batch of F4H-1s in 1961. Note the enlarged canopy and radome for the Westinghouse AN/ APQ-72 radar. **National Museum of Naval Aviation**

fuselage by nearly 8ft (2.4m), but the aerodynamic refinements and additional power raised the maximum speed to Mach 1.85. The most produced version of the Voodoo, 400 F-101Bs were built, as well as 79 TF-101B dual control trainer aircraft, later designated F-101F as they were fully combat capable. These aircraft were to serve with the Air Defence Command from September 1959 until April 1971, being supplied to Air National Guard units who kept them in service until September 1982.

The two-seat Voodoo was also supplied to the Royal Canadian Air Force, 112 CF-101Bs and 20 CF-101Fs serving with five squadrons between July 1961 and December 1984. Two Canadian Voodoos remained in service beyond this time, a single CF-101F trainer and a specially modified F-101B, equipped as an electronic warfare aircraft and designated as the EF-101B, which were not to retire until April 1987.

Twenty-two CF-101Bs were returned to the US in 1971 and modified as two-seat reconnaissance aircraft with forward and vertical cameras replacing the fire control radar, all of them being operated by the Nevada Air National Guard. The 807 single and two-seat F-101 Voodoos built were to have an excellent safety record, proving both reliable and popular with crews and maintainers. However, McDonnell's next aircraft was to surpass even this fine record.

PHABULOUS PHANTOM II

One of the most famous and enduring jet fighters of all time, the F-4 Phantom actually began in August 1953 as a project to solve the problems of an earlier aircraft. The limited performance of the otherwise excellent F3H Demon had been due to the failure of the J40 engine programme.

This led McDonnell's preliminary design manager Dave Lewis to examine alternative propulsion for the fighter, which other than a lack of thrust had excellent handling. Four concepts were studied, three of them twin engined, each in several variants with differing wing designs, two of which were tailed deltas. As there were no official requirements or competitions underway at the time, these studies resulted in a completely unsolicited proposal to the Bureau of Aeronautics for a high-performance all-weather fighter on September 19, 1953.

As there were no stipulated requirements, the aircraft was offered in single or two-seat versions, with alternative nose sections for air-to-air, air-to-ground or reconnaissance equipment being part of the proposal. The aircraft was also to be armed with four 20mm cannon or retractable rocket packs, as well as being able to carry a very wide range of weapons on nine hardpoints under the fuselage and wings. Of the proposals, the US Navy found the F3H-G and H models most interesting, ordering a full-scale mock up.

Both of these were single seat and twin engined, powered by a pair of Wright J65s or General Electric J79s respectively. The wing was delta in layout with a 45° sweep to the leading edge, the larger area being to take the increased weight. However, the fighter role would be fulfilled by the recently ordered Grumman F-11 Tiger and Vought F-8 Crusader for the foreseeable future, so the design was reworked with 11 hardpoints for weapons to become a fighter-bomber.

On October 18, 1954, after an inspection of the mock up, the US Navy ordered two prototypes of the design, designated YAH-1s and intended as cannon armed, single seat attack aircraft. However, after a review of fleet requirements, the US Navy decided that the attack role would be taken by the Douglas A-4 Skyhawk. On May 26, 1955, taking advantage of the flexibility of the original proposal, the order for the two prototypes was altered to develop a two-seat, missile armed, all weather, fleet defence fighter redesignated as the YF4H-1. This was the role the F3H Demon had mostly fulfilled during its career.

On July 25, the order was increased to cover five pre-production aircraft with 16 more added to this the following year, the General Electric J79 being the engine of choice, not least for its lower fuel consumption over the J65, which made the requested three-hour loiter endurance easier to achieve. The design team under Herman D. Barkey placed the engines low in the rear fuselage, each fed by a fixed geometry cheek intake.

The armament was set at four AIM-7 Sparrow III semi active radar homing missiles mounted in semi-recessed bays under the fuselage, with the option to carry AIM-9 Sidewinders on underwing pylons. The original cannon were deleted for the fleet defence role, making the YF4H-1 the first US missile only fighter. The wing was an anhedral delta design with a level tailplane at the base of the fin at this stage, but wind tunnel testing revealed that this configuration limited the performance to below Mach 2 and exhibited marked instability.

The changes made to the design to correct these problems were to later cause an RAF engineer responsible for receiving the first British Phantom to enquire if it had been delivered the right way up! The tests revealed the wing needed a 5° dihedral, which would mean completely redesigning the centre section, a major undertaking. Instead, 12° of dihedral were added to the outer wing panels, which could fold at this point reduce the space the new type required in carrier hangars. ➤

The 5000th Phantom built was this F-4E. 77-0290, with the elongated nose for the internally mounted M61 Vulcan 20mm cannon, here at St Louis on May 9, 1978. **McDonnell**

The outer panels also broadened in chord to give a distinctive dog tooth to the leading edge, while the single piece tailplanes were given 23.25° of anhedral. The air intakes were also modified with adjustable ramps to maintain subsonic airflow to the engines, which in the first prototype were 14,800lb (6713kg) thrust J79-GE-3A turbojets as the -8 version intended for the F4H-1 were not ready.

In this form, the first Phantom II, 142259, took to the air at St Louis on May 27, 1958, this first flight performed by Robert C. Little. Testing showed the air intakes required further modification, including the now familiar 12,500 small holes in the inner intake cheek door to extract the slow moving boundary layer air, preventing turbulent airflow in the intake ducts. In December 1958, the Phantom II was tested against the single engined Vought XF8U-3 Crusader III in the future fleet defence role, the Phantom II being declared the winner on December 17 as the US Navy decided that the high workload of a missile armed interceptor required a crew of two.

Also on that day, 24 more F4H-1s were ordered, bringing the total on order to 45. These first production F4H-1s were powered by the J79-GE-2 or -2A version of the engine, producing 16,150lb (7326kg) of thrust, and were known as F4H-1Fs until the common designation scheme introduced in 1962, when they became F-4As. Further modifications were made, including a revised canopy to improve the crew's view, a larger radome which increased the diameter of the nose to accommodate the Westinghouse AN/APQ-72 radar, further changes to the intake design and the addition of boundary layer control ducts to the leading-edge slats and trailing edge flaps.

Payload trials were carried out, including the carriage of an impressive 24 500lb (227kg) bombs on the fuselage and wing pylons. On February 15, 1960, the fourth preproduction aircraft, 143391, made the first launch and recovery aboard an aircraft carrier, CVA-62, the USS *Independence*, with US Navy service trials beginning in July that year.

Given the excellent performance of the new fighter, US Secretary of Defence Robert Strange McNamara directed the USAF to evaluate the F4H-1F to meet its need for a new interceptor, tactical fighter-bomber and reconnaissance aircraft. Starting in 1961, the Phantom II was tested against the Convair F-106A Delta Dart, the Republic F-105 Thunderchief and McDonnell's own F-101 Voodoo in these three roles, proving to have advantages in range, payload, turning performance, equipment and maintenance requirements in all three comparisons.

As a result, in January 1962, President John F. Kennedy requested Congressional approval for the acquisition of F-110A tactical fighters and RF-110A reconnaissance aircraft for the USAF. Two F4H-1s were transferred to Langley Air Force Base in Virginia on January 24 for evaluation by Tactical Air Command (TAC), with the result that in March, this type was selected as the fighter and tactical reconnaissance aircraft for TAC and the US Air Forces deployed in Europe and the Pacific.

The common designation scheme of September 1962 meant these were designated as the F-4C and RF-4C, the US Navy variant with the J79-GE-8 engines that had begun production while this work had been going on becoming the F-4B. This early success was to result in an incredible 5195 Phantom IIs being produced, 5068 by McDonnell Douglas, as it had become, the last being an F-4E for Korea delivered in October 1979. Mitsubishi Heavy Industries also built 127 Phantom IIs under licence for the Japan Air Self Defence Force, delivering their last F-4EJ in May 1981.

The Phantom II was to see extensive use with all three US armed forces in the Vietnam War, becoming the mount of a number of aces in the air-to-air role. In the Suppression of Enemy Defences (SEAD) role, better known as 'Wild Weasel', the F-4G and reconnaissance RF-4C were again in combat over Iraq during Operation Desert Storm in 1991. Aside from the USAF, US Navy and US Marine Corps who were to operate Phantoms until 1996, 1987 and 1992 respectively, 11 other countries were to acquire the Phantom II in a wide variety of versions, the first being the UK in 1964.

The Redstone booster carrying the first Project Mercury astronaut Alan B. Shepard, Jr. lifts off from Cape Canaveral at 9:34am Eastern on May 5, 1961. **NASA**

The air forces of Greece, Japan, South Korea and Turkey still operate upgraded versions of the Phantom II, which remains a viable combat aircraft to this day. A number of retired airframes were converted to QF-4 remotely piloted target drones, 314 by BAE Systems, the last being delivered in 2013.

SPACE DEVELOPMENTS

Also worthy of note at this juncture is the involvement of McDonnell in NASA's rapidly growing space programme. In 1958, the same year as the Phantom II made its first flight, McDonnell won the bid to produce 20 Mercury spacecraft for NASA, along with a number of training and test non-flying versions.

Five of these were never flown and two were destroyed in unmanned tests, but six were to make the first manned spaceflights in the US, the first being by Alan B. Shepard on May 5, 1961. That year, McDonnell was also selected to build the two-man Gemini spacecraft which was used on 10 manned missions to expand the US space capabilities in preparation for the Apollo programme and the first landing on the moon. The first Gemini mission was flown by Virgil I. 'Gus' Grissom and John W. Young on March 25, 1965, making three

This photograph, taken by Gemini VII crewmembers Jim Lovell and Frank Borman on December 4, 1965, shows Gemini VI in orbit 160 miles (257km) above Earth, the first rendezvous of two manned spacecraft in orbit. Gemini VI was crewed by astronauts Walter Schirra and Thomas Stafford. **NASA**

orbits of the Earth to test the Gemini's systems in flight.

McDonnell also built the unmanned ASSET winged re-entry vehicle which first flew on September 18, 1963, and was used to gather data on aerodynamic heating on re-entry into the Earth's atmosphere, and then investigate the necessary protective measures and structures that would be required to cope with the extreme temperatures and loads. Six ASSETS were flown, intended initially to provide date for the Boeing X-20 Dyna-Soar spaceplane, but this project was cancelled in December 1963.

The ASSET flight data would eventually be of use in the design of the Space Shuttle. This was another area where the abilities of both McDonnell and Douglas were well matched, Douglas having built the Nike, Skybolt and Thor missiles, the latter being developed into the Delta series of launch vehicles for both NASA and the US Military, with the Delta II and Delta IV still being in use today to launch a wide variety of payloads.

The Delta programme also lead to Douglas's selection in 1960 by NASA to build the S-IVB which was used as the second stage of the Saturn IB and the third stage of the Saturn V, the launch vehicles for the Apollo and Skylab programmes.

Given the close affiliation of the companies and their products, the first talks of the possibility of a merger began as early as 1963, Douglas accepting McDonnell's bid in 1966 and officially merging to create the McDonnell Douglas Corporation on April 28, 1967.

WIDE BODY AIRLINER

Douglas had entered the USAF's CX-HLS competition for a large military transport aircraft in 1964, and although this was won by the Lockheed C-5 Galaxy, Douglas had

The Delta launch vehicle is composed of parts from the Thor, an intermediate-range ballistic missile, as its first stage, and the Vanguard as its second. The first Delta was launched from Cape Canaveral on May 13, 1960, and has been used to launch civil, commercial and military satellites into orbit. **NASA**

acquired a great deal of experience with large turbofan powered aircraft from the programme.

Studies were begun into the first iteration of the DC-10, a twin-deck four-engined airliner capable of carrying up to 650 passengers, but this elicited little response from the airlines. In April 1966, Pan American World Airways began ordering the Boeing 7 4 7, a less ambitious project than the first DC-10 concept, followed later that year by interest from American Airlines in acquiring a twin engined wide bodied airliner for 250 passengers, but capable of using the confined spaces of La Guardia Airport in New York.

Douglas conducted its own studies, favouring a three engined design for its ability to operate from hot and high airfields and to give the aircraft transcontinental range. With the merger and formation of McDonnell Douglas in April 1967, Robert Hage became the programme manager and the DC-10 was to become the first new aircraft produced by the company, keeping its original Douglas designation.

The three engined design with its twin aisle interior could seat between 250 and 350 passengers depending on cabin layout, and was offered with a choice of the Pratt & Whitney JT9D or General Electric CF6-6 turbofans. The first orders for the new aircraft came in 1968, with American Airlines purchasing 25 with options for 25 more on February 19. However, the rival Lockheed Tristar programme shocked McDonnell Douglas when 144 orders ➤

The ASSET re-entry research vehicle seen mounted on top of its launch booster. **Boeing**

The prototype DC-10 was rolled out at Long Beach in August 1970 and is seen here later in the year at San Diego. **San Diego Air and Space Museum**

from five customers were announced only six weeks after the first DC-10 order.

This caused the board of McDonnell Douglas to seriously consider cancelling the DC-10, until, in April, United Airlines ordered 30 aircraft with options on 30 more. The prototype DC-Hl-10, powered by three CF6-6 engines, flew for the first time from Long Beach to Edwards Air Force Base for testing on August 29, 1970, captained by Clifford L. Stout. Produced in four major variants in medium range 'domestic' and long range 'international' versions, there were also a number of specialised sub types for such roles as a combination passenger and cargo aircraft, the 'domestic' ranged DC-10-10 first entering commercial service on August 5, 1971, with American Airlines.

During its career, the DC-10 was to suffer some notable accidents, two of which were caused by the failure in flight of the cargo loading door, the second of which on March 3, 1974, caused the deaths of all 346 people aboard when Turkish Airlines Flight 981 crashed near Paris, France. Although the door system was modified and the DC-10 went on to prove itself a reliable and safe aircraft, the unfavourable publicity surrounding these accidents affected sales, and the hoped for target of 1000 aircraft built was never realised.

Altogether 386 DC-10s were produced for the airlines of the world, eventually being used by 73 countries. The last aircraft built, a DC-10-30 for Nigerian Airways, was delivered on July 27, 1989, but the commercial passenger use of the DC-10 was to continue until February 20, 2014, when Biman Bangladesh made its last passenger flight from Dhaka to Birmingham in the UK.

A number of cargo conversions are still in service today, with cargo airline FedEx Express being by far the largest operator with 60 DC-10-10s and -30s still in service, many converted to the MD-10 standard, of which more later.

The DC-10 airframe was to see two major developments, the first of which was as the KC-10A Extender flight refuelling tanker and military transport aircraft for the USAF. In 1975, the USAF had begun the Advanced Tanker/Cargo Aircraft (ATCA) programme to supplement the existing KC-135 fleet and increase its strategic airlift and deployment capabilities.

After a long selection procedure, the DC-10 was confirmed as the winner over a Boeing 747 based proposal with an order for 20 aircraft being placed on December 19, 1977. The KC-10A was based on the combination passenger and freighter DC-10-30CF model, powered by the General Electric CF6-50C3 version of the turbofan which produces 52,500lb (23,814kg) of thrust Able to carry 54,455 gallons (206,130 litres) of fuel, three times the amount of the KC-135, the first KC-10As were fitted with a McDonnell Douglas designed flying boom refuelling system on the centreline of the rear fuselage, with an additional retractable drogue type hose drum installed slightly to starboard.

The prototype first flew on July 12, 1980, the order for the type being increased to 60 aircraft as its utility was fully realised, the range and fuel capacity of the tanker meaning it could fully support the deployment of tactical aircraft worldwide, refuelling them while carrying their support personnel and equipment. In cargo-only configuration, the KC-10A can carry 170,000lb (77,110kg) of payload, or 146,000lb (66,225kg) along with 75 support personnel.

The last KC-10A built for the USAF was delivered on November 29, 1988, and used for trials with a pair of Flight Refuelling Mk.32B hose drum pods, one under each wing, in addition to the standard refuelling equipment in the fuselage. The three point tanker trials were a success, with sufficient of the removable pods being purchased to equip 40 of the aircraft. In 2010, Boeing upgraded the remaining 59 KC-10As with new avionics including the communication, navigation, surveillance and air traffic management (CNS/ATM) system to allow continued operation of the type in civil airspace, while Rockwell Collins carried out a cockpit modernisation programme beginning in 2011.

The KC-10A fleet has supported every single major deployment by US forces including operations over Libya, Iraq, the Balkans and Afghanistan and was not originally intended to retire until 2043. However, sequestration and budget cuts may bring this forward despite the cost effectiveness of the fleet and its reliability.

Aside from the KC-10As for the USAF, two civil DC-10-30CFs were converted to KDC-10 tanker transports for the Royal Netherlands Air Force in 1994, both of which are still in use today, and two more DC-10-40s were converted to KDC-10 tankers, fitted with both refuelling systems for Omega Air Refuelling Services and Global Air Tanker Service.

Other than the military tanker transport versions, the other development of the DC-10 design began on July 29, 1985, when an aerodynamically refined, stretched and upgraded version of the DC-10 with a fully glass cockpit was offered to airlines. The programme was officially launched on December 30, 1986, with orders from 10 airlines and two leasing companies totalling 52 aircraft and options on 40 more.

Designated as the MD-11, problems in production including delays from suppliers and strikes meant the first flight was delayed until January 10, 1990, with the first delivery being made to Finnair on December 7 after test and certification flying had been carried out. A lack or range and higher than expected fuel consumption affected sales, but McDonnell Douglas responded with the Performance Improvement Programme which solved all of these issues by 1995.

Unfortunately, competition from Boeing and Airbus had captured the majority of the market by this time, so only 200 MD-11s were built, the majority being built as combination passenger and freight carriers or cargo aircraft only, many later being

The KC-10 Extender is both a tanker and a transport aircraft, seen here refuelling a Rockwell B-1B bomber. **USAF**

converted to this role, the last new build MD-11F being a cargo aircraft delivered to Lufthansa Cargo on February 22, 2001. World Airways still has one passenger MD-11 in its fleet, while KLM still use four of the passenger versions which are scheduled to make their last commercial flight on October 25, 2014.

Two other developments are worthy of note in the DC-10 story, the first of these being the two DC-10s converted to DC-10 Air Tankers in March 2006 and July 2008 for 10 Tanker Air Carr ier, a firefighting company based at Victorville in California. The first aircraft, Tanker 910, is based in California, and has been used to fight fires in nine states of the US since its entry into service.

The second aircraft, Tanker 911, has been similarly used in the US, but was also deployed to Australia in 2010 to fight fires in Victoria state. Both aircraft can carry up to 12,000 US gallons (45,000 litres) of water or fire retardant in an external tank mounted under the centre section of the aircraft, which it can release in eight seconds.

The second development is the MD-10, essentially a DC-10 with the avionics and glass cockpit of the MD-11, known as the Advanced Common Cockpit. This is of particular use to FedEx Express, which operates both types of aircraft and so can conduct both training and operations with the same pool of aircrew. The DC-10/MD-10 fleet will begin to be replaced in 2014 with the first deliveries of the Boeing 767-300F.

BIRDS OF PREY

As has been already mentioned in the first article in this issue, the theory of Energy-Manoeuvrability (E-M), which was published in 1964, was applied to the TFX programme jointly being developed under duress by the USAF and US Navy as the F-111. This theory revealed how poorly the F-111 would perform in any kind of close combat, largely due to its excessive weight.

These findings caused the USAF to reestablish its original F-X long range fighter requirement independently of the TFX programme with the issuance of an RFP on December 8, 1965. F-X was rewritten in the light of E-M theory, cutting the required loaded weight by over a third to 40,000lb (18,144kg) and specifying a maximum speed of between Mach 2.3 and 2.5. Essentially, the priority for the new fighter was to be able to defeat any known or projected threats in air-to-air combat. The ability to carry out air-to-ground missions was a secondary role.

As already mentioned, the discovery of the MiG-25 in 1967 gave a tremendous boost to the F-X programme. Studies were undertaken by several aircraft manufacturers in March 1966 and December 1967, with contracts being awarded for project definition studies to Fairchild-Republic, North American and McDonnell Douglas on December 30, 1968.

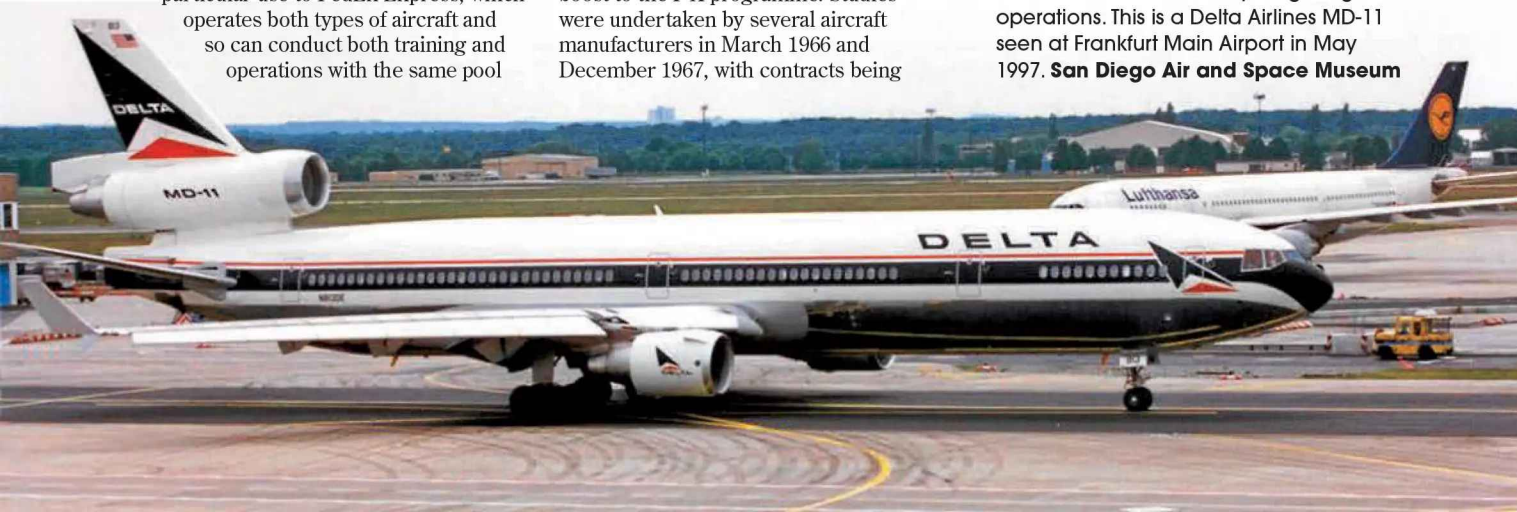
The prototype F-15 over Edwards Air Force Base, note the early square wingtips and straight leading edge to the tailplane. **USAF**

An F-15C with the FAST packs or CFTs about to be fitted. The tanks could still carry the AIM-7 Sparrow missiles and actually served to reduce drag at subsonic speeds. **USAF**

On December 23 the following year, after additional technical proposals, the McDonnell Douglas entry was declared the winner and the F-15 Eagle began detail design at St Louis, the team led by Donald Malvern and Richard Noyes.

Taking the data from NASA configuration wind tunnel testing and its own experience with experiments on the F-4 Phantom II, the F-15 design took shape around a pair of the powerful Pratt & Whitney F100 afterburning turbofans in the rear fuselage and a large, shoulder mounted wing to increase manoeuvrability through low wing loading. The broad, centre fuselage also helped in this regard, its flat surfaces providing a great deal of lift.

The twin fins began at the trailing edge of the wing and the all-moving tailplanes were mounted on the rear sides of the fuselage protruding far aft of the engine exhausts. A great deal of weight was ➤



The MD-11 was an enlarged DC-10 with improved aerodynamics, systems and avionics intended for very long-range operations. This is a Delta Airlines MD-11 seen at Frankfurt Main Airport in May 1997. **San Diego Air and Space Museum**

An F-15D two seat trainer version of the Eagle dropping flares. The trainers maintained the combat capabilities of the single seat aircraft, and led to the development of the F-15E Strike Eagle. **USAF**

A pair of F-15A Eagles of the 33rd Tactical Fighter Wing showing the four AIM-7 Sparrows mounted on the fuselage 'corners' and four AIM-9 Sidewinders on the underwing pylons. **USAF**

saved in this area by the extensive use of composite materials, producing extremely thin yet strong tail surfaces.

The engines were fed via two large complex intakes with a variable diffuser, bypass door and three ramps which would automatically maintain the engine airflow even at high angles of attack. The cockpit was a fighter pilot's dream, a large bubble canopy with a single frame and a high mounted seat gave the pilot an unparalleled view in all directions. The Phantom II had been redesigned as a two-seat aircraft because the workload of a radar-equipped interceptor was considered too high for a single pilot.

Not so with the F-15, as advanced avionics were integrated into a 'hands on throttle and stick' (ROTAS) cockpit environment based around the powerful Hughes, now Raytheon, AN/APG-63 X-band radar with both look up and look down capabilities and a range of 100 miles (160km). An automated feature of the radar was that it could project target information directly onto the Head Up Display (HUD) in short range engagements, indeed, information from the entire navigation, Electronic Warfare Warning System (EWWS), communications and countermeasures suite of avionics could be displayed on the HUD, as well as vital flight data, all managed via a central digital computer.

Radar target data was also fed to the computer for weapons aiming. The whole cockpit and avionics suite was designed so the pilot could fly and fight the aircraft without moving his hands or looking down, keeping his situational awareness and giving the F-15 a tremendous advantage in air-to-air combat. The F-15 was designed to carry four AIM-7 Sparrow missiles on mounts on the outer corners of the centre fuselage sides, with more, or AIM-9 Sidewinder missiles able to be carried on the two underwing pylons.

These and the single centreline pylon could also carry external fuel tanks or other weapons in the air to ground role. The lessons of the F-4 over Vietnam, which in its early versions did not carry a gun, were learned and an M61A-1 Vulcan 20mm cannon was fitted in the short leading edge root extension of the starboard wing.

The first order from the USAF was for 20 full scale development aircraft, 18 single seat F-15As and two TF-15A two-seat trainers. Powered by two Pratt & Whitney F100-PW-100 turbofans that produced 23,830lb (10,809kg) of thrust in afterburner, the prototype first flew at Edwards Air Force Base on July 27, 1972, in the hands of chief test pilot Irving L. Burrows, after having undergone extensive ground testing at St Louis.

During initial flight testing, a buffeting problem resulted in the redesign of the wingtips; the original square tips being cut back to their now familiar triangular shape with a swept back trailing edge. Flutter encountered in the tailplane was cured by adding a dogtooth notch in the leading edge of the tailplane at about one third span. Problems with the development of the engine were to delay the flight testing of the F-15, which meant the first aircraft were not cleared for delivery to USAF squadrons until November 1974.

The astounding performance of the F-15, not least its ability to accelerate in a vertical climb, meant that orders were quickly increased, with 384 F-15As and 57TF-15As produced after the first 20 FSD aircraft. One F-15A was used in the trials of the Vought ASM-135A air launched anti-satellite missile between 1983 and 1988, while 24 F-15As and two TF-15As were supplied to the Israeli Air Force in 1977, the first of five export customers for the air superiority fighter.

Two major upgrades were initiated while the F-15A was in service, the first being conformal additional fuel tanks which could

The first production F-15E Strike Eagle, 86-0183. **USAF**

be fitted along the sides of the fuselage, known as Fuel and Sensor Tactical (FAST) packs or Conformal Fuel Tanks (CFTs).

These actually decreased the drag on the airframe at subsonic speeds and included the mounts for the AIM-7s that were originally on the fuselage corners. The second upgrade was part of the Multi-Stage Improvement Programme (MSIP) begun in 1983.

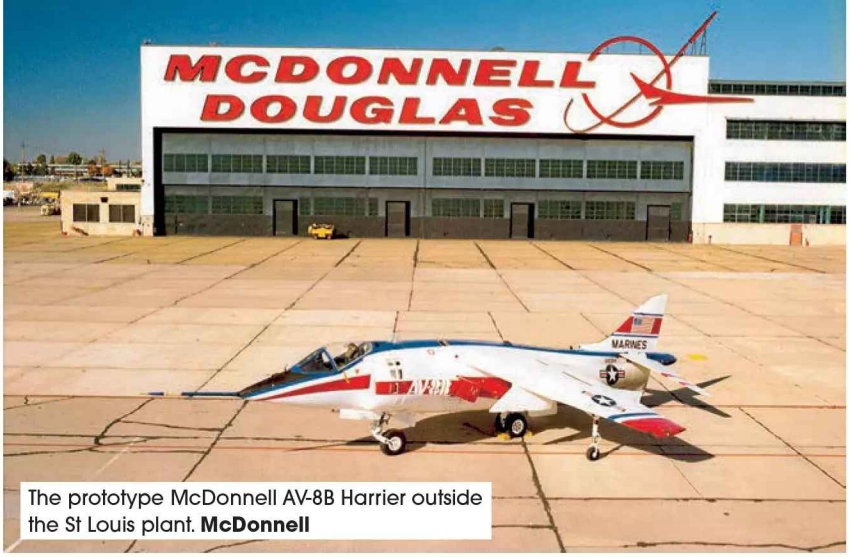
The EWWS was upgraded to the Tactical Electronic Warfare System (EWS), including the ALR-56C Radar Warning Receiver and the ALQ-135 Electronic Countermeasures system. By far the most important part of the MSIP were the changes to the APG-63 radar which had a tenfold increase in memory capacity and trebled processing speed. It also included the Programmable Signal Processor (PSP) which allowed updates of new radar modes and weapons through software reprogramming rather than hardware changes, greatly increasing the adaptability of the system. One of the TF-15As was also used to test the FAST packs as well as the Pave Tack laser designation pod and Low Altitude Navigation and Targeting Infrared System for Night (LANTIRN) pod.

The F-15A was followed by the F-15C, the TF-15A being redesignated F-15B with the introduction of this variant. Between 1979 and 1985, 483 F-15Cs were built, along with 92 of the equivalent two seat version, the F-15D.

The new version had increased internal fuel capacity and the ability to carry the CFTs, a stronger undercarriage and braking system being fitted to cope with the increased weight of 68,000lb (30,844kg). The MSIP upgrades were incorporated either on the production line or retrofitted to the first blocks of F-15Cs and Ds built.

The engine was changed to the F100-PW-220 version of the turbofan, which, while reducing the available thrust by 380lb (172kg), greatly increased the reliability of the engine. The F-15C and D could also carry air-to-ground weapons on the CFTs or pylons, and were cleared to drop a variety of bombs at supersonic speeds. Export versions of the F-15C and D were also supplied to Israel and Saudi Arabia, those for Israel having an extended air-to-ground capability.

The F-15C was also the basis for the F-15J, the first two being built in St Louis for the Japan Air Self Defence Force, with 139 being built under licence by Mitsubishi Heavy Industries. McDonnell Douglas also built the first 12 F-15DJ two-seat trainers,



The prototype McDonnell AV-8B Harrier outside the St Louis plant. **McDonnell**

with an additional 25 being built in Japan, the construction of both types taking place between 1981 and 1997.

The AN/APG-70 version of the F-15's radar was developed in the early 1980s, with a hardware redesign and the ability to incorporate new modes and enhanced capabilities. This radar had many modules in common with the AN/APG-71 in the F-14 Tomcat and the AN/APG-73 in the F/A-18 and was developed as such to reduce development costs. Initially installed on late production F-15Cs and Ds, the AN/APG-70 was to be predominantly fitted to the two-seat F-15E Strike Eagle where it's enhanced air-to-ground modes were particularly useful.

In the F-15Cs and Ds, the AN/APG-70 was later replaced by the upgraded APG-63 radar in the early 1990s. The (V)1 version featured a hardware redesign to ease maintenance and reliability while providing greater growth potential in the system. This was retrofitted to 180 F-15s, and was followed by the (V)2 with an Active Electronically Scanned Array (AESA) antenna then the (V)3 which improved still further on this technology and is to be fitted to 178 F-15Cs and Ds along with the Joint Helmet Mounted Cueing System. The improvements in the radar took full advantage of the capabilities of the AIM-120 AMRAAM air-to-air missile introduced in 1991.

As already mentioned, the two-seat F-15 was developed into the final major production variant, the F-15E Strike Eagle, which first flew on December 11, 1986, 236 being built for the USAF up to 2001. This featured a strengthened structure and was powered by the F100-PW-229 turbofan which produced 29,000lb (13,154kg) of thrust which enabled it to operate at an increased weight of 81,000lb (36,741kg).

While retaining the air-to-air capabilities of the earlier Eagles, the F-15E can carry up to 23,000lb (10,400kg) of a wide variety of bombs and missiles in the air-to-ground role. To assist in targeting these weapons, the F-15E can also carry the LANTIRN pod, or the upgraded Sniper XR and LITENING sensor and targeting pods.

The F-15E has also been the basis for several export models, 25 F-15Is for Israel, 61 F-15K Slam Eagles for Korea, 72 F-15Ss and 84 SA upgrades and new build aircraft for Saudi Arabia and 24 F-15SGs for Singapore. Aside from operational use by Israel, the USAF F-15Cs, Ds and Es were to see combat over Afghanistan, Iraq, Libya and the former Yugoslavia in both the air-to-air and air-to-ground roles, Saudi Arabian F-15Ss being used in combat operations over Iraq. The last F-15A and B Eagles were withdrawn from US service in 2009, but it is likely the later models will remain in service beyond 2025, and longer still with the export customers.

The last major project begun by McDonnell Douglas prior to its involvement in the F/A-18 programme was the highly developed version of the British Harrier vertical take-off and landing ground-attack aircraft for the US Marine Corps, the AV-8B Harrier II. Suffice to say that the project gave McDonnell Douglas tremendous structural experience in building in composites. The forward fuselage, tail, and entire wing were constructed with epoxy bonded carbon fibre and other similar materials, 26% of the aircraft's airframe being made of composites.

Aside from the TAV-8B two seat trainer version, the AV-8B was produced in single seat versions as a day attack, night attack and fighter version, the Harrier II Plus. This was fitted with the Hughes AN/APG-65 radar, the same system developed for the F/A-18, in which form the Harrier II Plus was supplied to the US Marine Corps and the Italian and Spanish Navies. Between 1981 and 1997, 337 AV-8Bs were produced by McDonnell Douglas, the RAF versions being built in the UK by British Aerospace. These aircraft were to see combat over Afghanistan, Iraq, Libya and the former Yugoslavia with the US Marine Corps, over Afghanistan, Kosovo and Libya with Italy and over Bosnia with Spain.

Upgrades programmes were to continue until 2003 and the US Marine Corps expects to keep the type in service until at least 2030 until replaced by the F-35B.

As can be seen from the last two articles, throughout its history McDonnell Douglas had steadily developed precisely the experience and expertise required to fully partner Northrop in the development of the F/A-18, as will be covered in the next article.

■ Words: *Tim Callaway* ➤

From Model 267 to Hornet

The development of the F/A-18A and B

The US Navy announced that the McDonnell Douglas and Northrop entry had won the NACF competition on May 2, 1975. With this success, the detail work of producing the fighter really began, leading to a change in designation and role and later to a falling out between the partner companies.

The basic design work of turning the YF-17 into a carrier-based aircraft had been completed by McDonnell Douglas to produce the Model 267, but a great deal of detail work was required before the drawings and proposals would become a prototype.

While provision had been made for the carriage of the additional weapons required by the strike role and the undercarriage and airframe had been strengthened to cope with the stresses of carrier operations, many further changes would be required as the final form of the aircraft, and the requirement behind it, were defined and finalised.

One of the early decisions was to change the radar fitted to the aircraft to a much more powerful and capable system to allow a full range of weapons to be carried and delivered. In late 1977 the radar of choice was the Hughes, now Raytheon, AN/APG-65, an advanced multi-mode system compatible with the AIM-7 Sparrow missile and other weapons intended for the aircraft.

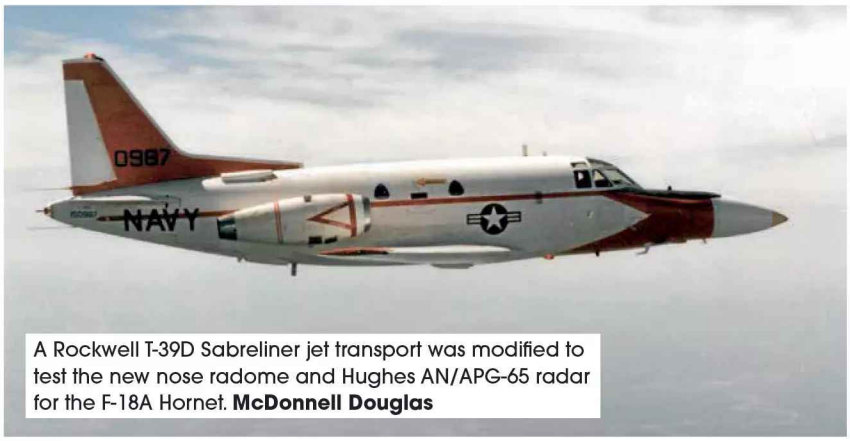
As Northrop and McDonnell Douglas began to iron out the details, a plan also emerged for the production of the aircraft based on the fact that while McDonnell Douglas was going to be the lead contractor to the US Navy on the carrier-based version, Northrop would lead the development of a land based aircraft that it hoped to sell to the export market with the same level of success it had enjoyed with the F-5 Freedom Fighter.

The production line was split at an early stage into two logical halves. Northrop would produce the centre and rear fuselages, fins and rudders and integrate all the fuel, hydraulic and electrical systems into these elements of the airframe. The completed units would be shipped to St Louis, where McDonnell Douglas would build the tailplanes, wings, forward fuselage and cockpit, and run the final assembly line.

This successful split of responsibilities was to run for the length of the F-18 programme and be a feature of every aircraft produced. The design developments were formally approved by the US Navy with the issuing of a contract to McDonnell Douglas for 11 development aircraft in January 1976. On March 1, 1977, the aircraft was officially named, the Secretary of the Navy W. Graham Claytor stating that the new strike fighter would be called the Hornet.

Like the YF-17 before it, the F-18 featured significant use of advanced and composite materials in its structure, with carbon fibre being over 10% of the total weight of the aircraft and glass fibre making up nearly another 12%. Aside from the construction, there were other unusual and innovative elements in the equipment for a fighter of the day, including an auxiliary power unit that could start the engines or provide electrical, pneumatic and hydraulic power on the ground. This was particularly useful at the kind of remote bases the US Marine Corps often found themselves deployed to, where there was little in the way of ground support equipment.

Inside the cockpit was where the Hornet's technological heart lay however, with a Hands On Throttle and Stick (HOTAS) layout designed in from the start, with flight and sensor information being



A Rockwell T-39D Sabreliner jet transport was modified to test the new nose radome and Hughes AN/APG-65 radar for the F-18A Hornet. **McDonnell Douglas**

Another of the potential customers who evaluated the YF-17/F-18L concept was France, the second prototype seen here in French Air Force markings. The YF-17s were to appear in a host of national markings, including Greek and Spanish, during the long sales drive. **Northrop**

displayed on a Head Up Display (HUD) and two large multifunction CRT displays. The controls were linked by a fully digital quadruplex flyby-wire system, the first to be installed in a fighter, and the entire avionics and electrical system could be quickly checked prior to start up by comprehensive Built In Test (BIT) equipment.

The implementation of all the design changes and the integration of the advanced radar and other systems delayed the rollout of the prototype at St Louis until September 13, 1978. After systems and taxi trials, test pilot Jack E. Krings took F-18 prototype 160775 into the air for the first time at Lambert Field on November 18. The success of the early flights meant that the evaluation and trails by the US Navy began in January 1979 at the Naval Air Test Center at Patuxent River and were followed by the carrier qualifications of the new fighter on board the USS *America* (CV-66).

The third prototype, 160777, was used for the qualification flights, which were conducted off the Virginia Cape on October 30, 1979. It was the advanced technology at the heart of the Hornet that was to result in a change in its designation and its planned orders by the US Navy. As already mentioned, plans were in place to acquire 780 of the new type in three initial variants, the F-18A single seat fighter, the A-18A single seat attack aircraft and the two seat TF-18A combat capable trainer.

The differences between the two single seat versions were minor, largely matters of avionics and sensors for the different weapons the roles required. McDonnell Douglas redesigned weapons stations 4 and 6, those on the fuselage corners, to be able to carry sensor pods as well as weapons and integrated these into the mission computer software. In the fighter role, the stations carried the AIM-7 Sparrow air-to-air missile.

In the strike role, the port station carried the AN/AAS-38 forward looking infrared pod and the starboard the AN/ASQ-173 laser spot tracker. Since the cockpit was already fully fitted with modern and flexible information displays, it only took a careful detail redesign and integration of the avionics suite to fully merge the fighter and attack versions into a single aircraft that maintained all the capabilities required of both.

By 1980, the Hornet was unofficially being called the F/A-18A and the trainer the TF/A-18A. On April 1, 1984, the new designation for the single seat aircraft became official, with the two seat Hornet becoming the F/A-18B.

While McDonnell Douglas was working on the naval variant, Northrop was developing its own modifications for a land-based version of the aircraft known as the F-18L. While this offered the same avionics and engines as the F/A-18A, it was much lighter, not requiring either the wing folding mechanism or the strengthened undercarriage and airframe of the naval variant.

Because of the lack of a fold, the wing was much stronger, the wingtip rails being able to carry the AIM-7 Sparrow as well as the AIM-9 Sidewinder and an additional pair of underwing weapons pylons being fitted. The lighter undercarriage included a single nosewheel and a lighter arrestor hook, in all making the F-18L a projected 30% lighter than the F/A-18A.

The F-18L also had greater weapons capacity and was built with a design load stress of 9G, as opposed to 7.5G for the F/A-18A. The market for the F-18L seemed large and lucrative, but Northrop was not to sell a single aircraft. The F-16, being the lightweight fighter of choice for the USAF, had already attracted the ➤

A top view of one of the nine single seat FSD F-18As, showing the notched leading edge of the wing and allowing a direct comparison... **McDonnell Douglas**

...with the shape of the original Northrop YF-17 Cobra. Note the open Boundary Layer Air Discharge slots between the fuselage and leading-edge root extensions, later to be almost fully closed on production aircraft. The YF-17 has been painted in Canadian markings and bears the legend 'Prototype CF-18L' on the rear fuselage. Canada was impressed by the F-18L, but eventually bought the F/A-18A as the CF-18. **McDonnell Douglas**

Left: The first of the FSD two-seat aircraft, initially called TF-18As.The two-seat aircraft maintained all of the combat capabilities of the single seat, the second cockpit only costing 6% of the internal fuel capacity. **McDonnell Douglas**

attention of many of Northrop's former customers for the F-5, who were seeking greater interoperability across NATO and other allied air forces.

The twin engine F-18L was a more expensive, complex and heavier aircraft than the F-16, and those overseas customers that did express an interest were more interested in the capabilities of the naval version to solve particular needs, even with purely ground based air forces. Northrop could see its market disappearing between the products of General Dynamics and its own partner company, so in October 1979 filed a lawsuit against McDonnell Douglas in an attempt to forbid them from selling the F/A-18A overseas and from using Northrop developed technology to break the terms of their original market agreements.

This sad and costly affair dragged on until 1985, when the two companies reached a settlement and McDonnell Douglas bought the design rights to the F/A-18 outright. Although Northrop cancelled the F-18L, the project was far from a loss as it was still to produce half the structure and systems of every aircraft built of the very successful F/A-18 series.

While all this was going on, the flight and service trials and evaluations of the F/A-18A and B prototypes were continuing and uncovered a number of problems with the aircraft. Most of these were easily solved in development, but one problem was to be a criticism of the Hornet that would never truly be solved, although it would be greatly improved.

The first snag was that the take-off roll was very long and the speed at which the nosewheel lifted was excessive. This was cured by two relatively simple fixes. Firstly, the 'dog tooth' notch in the leading edge of the tailplane, which had been designed to prevent tailplane flutter, was found to be unnecessary and was dispensed with, increasing the effectiveness of the tailplane at slow speed. Added to which, a system was developed where the rudders were toed in automatically on take-off which improved performance markedly.

The acceleration of the F/A-18 at airspeeds above Mach 1 was found to be inadequate with the early version of the engines, a problem that would be solved through improvements to the F404 turbofan during the test programme. The main undercarriage legs were found to be insufficiently strong on testing, an important factor in a carrier aircraft, so the main oleos were changed on the production line for a stronger twin-chambered type.

The seventh FSD F/A-18A Hornet showing a typical weapons load in the strike role, with four LGBs, a low altitude LGB is on the centre pylon, and an AGM-88 HARM anti-radiation missile, while still carrying self-defence AIM-9 Sidewinders on the wingtip rails. The two sensor pods on the fuselage 'corner' stations are one of the features that allowed the fighter and attack versions of the Hornet to become one aircraft. **McDonnell Douglas**

The roll rate was found to be less than specified, a situation exacerbated by insufficient stiffness in the outer wing panels, particularly when carrying a heavy weapons load. The outer wing section was stiffened and the ailerons increased in area, which improved the roll rate to within specification. However, the next change would improve it still further as a side effect.

The major problem experienced with the first test versions of the F/A-18, and one which still affects the aircraft today, was a lack of range. An increase in the internal fuel capacity of the later models went a long way to addressing this, but the high parasitic drag of the aircraft in its original form was dealt with before the first production batch was delivered in an attempt to improve the initially poor figures.

The slots between the leading-edge root extensions and the fuselage sides, known as Boundary Layer Air Discharge slots or BLADs, were almost completely filled in with the exception of a small slot about 20% of the length of the original. The longer slots were designed to allow a clean airflow to reach the fins and rudders at high angles of attack, but the drag penalty was far too high.

The redesigned smaller slot was just to bleed excess air from the engine air intakes. Like the tailplane, the 'dog tooth' notch on the leading edge of the wing was found to be unnecessary, so it too was removed, reducing the drag still further. While this improved the range through reduced drag, the filling in of the BLADs caused a problem with the fins. The vortices created by the leading-edge root extensions were now striking the fins, the extremely high air loads causing cracking in the base of the vertical surfaces that led to the F/A-18 fleet being grounded for part of 1984.

The fins were strengthened, which immediately cured the cracking, but a long-term solution was adopted in 1988, when a short, thin, broad flat plate was retrofitted to the top of the leading-edge

Caught exactly at the moment of touchdown on the USS *George H. W. Bush* (CVN-77), this F/A-18A+ of VFA-87 shows exactly why the Hornet was such a game changer for the US carrier-based air forces. Note the aircraft is still carrying an LGB on the stores station nearest the camera. Prior to the Hornet, all unused weapons had to be jettisoned, an expensive waste. Now, the tough Hornet can bring unexpended ordnance back to the carrier. **Luigino Caliaro**

root extensions. These plates changed the shape of the vortices that the extensions created and redirected them away from the fins, solving the problem permanently. In addition, the changed airflow provided an improved control response, especially in roll, improving the roll rate still further as an unforeseen side effect.

Having said that the range of the F/A-18 came in for criticism, it is worth noting that this was the one performance factor that did not meet or exceed the specification for the type. In all other parameters, the aircraft performed superbly, particularly in weapons delivery accuracy. To put it in perspective, the F/A-18A in the air-to-air or escort role still had a greater range than the F-4 Phantom II, but was found to be around 12% under the range of the A-7 Corsair II in the strike attack role, these both being aircraft the F/A-18 was intended to replace.

Despite this one flaw, the F/A-18 was a far higher performance aircraft than either of its predecessors, achieving multi-role flexibility at greatly reduced operating costs. The advantages and the advances the aircraft represented, particularly in terms of effectiveness, reduced pilot workload and flexibility of operation, and meant the US Navy did not hesitate in ordering the Hornet, the first production example flying on April 12, 1980.

Test and operational evaluations took place with VX-4 at Point Mugu and VX-5 at China Lake, before the first F/A-18A training squadron, VFA-125, began to receive its first Hornets in February 1981 at NAS Lemoore in California. The first operational squadrons to equip with the Hornet were VMFA-314 and 323 with the US Marine Corps at MCAS El Toro in January and March 1983, then VFA-113 and 25 of the US Navy at NAS Lemoore later that same year.

Of the F/A-18A, 380 were built for the US Navy and Marine Corps, including the first nine prototype or full-scale development aircraft. Alongside these were 41 F/A-18B two seat aircraft, again including the two prototypes. More of the early Hornet models were to be produced for Australia and Canada, where they were known as the CF-18, but these will be covered later.

■ Words: *Tim Callaway*

NATO'S CONTRIBUTION

A single F/A-18A, 161214, was modified with an extended nose section under the space usually occupied by the M-61A cannon. In this extended space, a twin sensor reconnaissance package was fitted to evaluate the Hornet as a possible replacement for the RF-4B. The package could be fitted and removed in a night, to return the aircraft to a standard configuration if required.

The F/A-18(R) as it was referred to first flew on August 15, 1984, and was evaluated by McDonnell Douglas and the US Navy with a variety of sensors, medium and low altitude cameras and infrared linescan among them. With the advent of the Advanced Tactical Reconnaissance System (ATARS), which could be fitted into the standard cannon bay in just a few hours, the concept of a dedicated reconnaissance version was dropped.

A rare image of the reconnaissance Hornet, the F/A-18(R), 161214. The aircraft was later handed over to NASA. **US Navy**

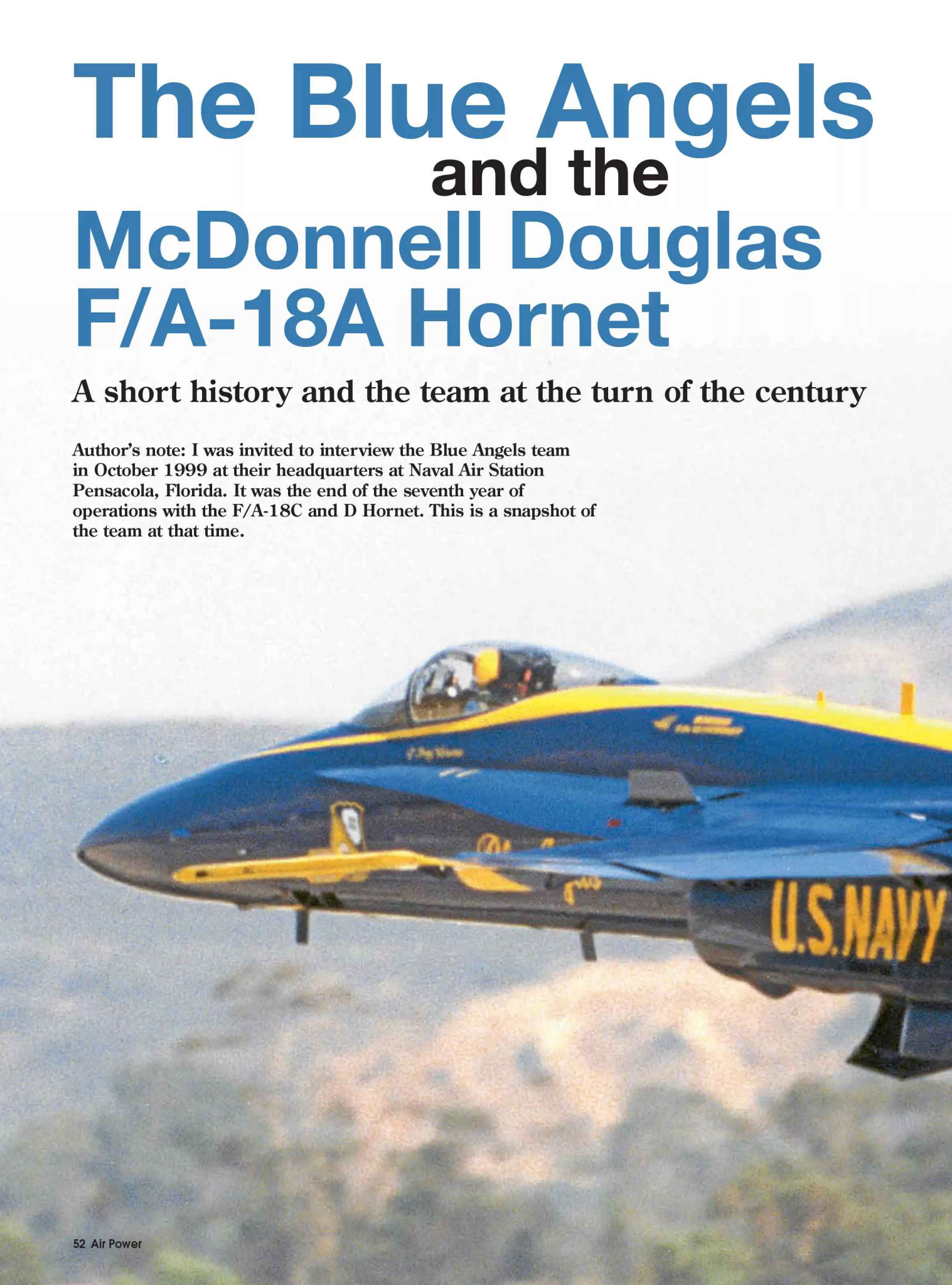
A mockup of the two-seat strike version of the F-18L showing the stronger wing with its increased number of pylons and ability to carry the heavier AIM-7 Sparrow on the wing tip rail. **Northrop**

Left: The F/A-18A and B were also purchased by the Royal Australian Air Force, where the types' reliability became something of a legend. **RAAF**

The Blue Angels and the McDonnell Douglas F/A-18A Hornet

A short history and the team at the turn of the century

Author's note: I was invited to interview the Blue Angels team in October 1999 at their headquarters at Naval Air Station Pensacola, Florida. It was the end of the seventh year of operations with the F/A-18C and D Hornet. This is a snapshot of the team at that time.



THE BEGINNINGS

Admiral Chester W. Nimitz, Chief of Naval Operations, issued the orders that led to the creation of the first Navy Flight Exhibition Team. Named the Blue Angels, the team was formed up in 1946 by a group of combat veteran pilots led by one of the most experienced pilots in the Navy; Lieutenant Commander R. M. 'Butch' Voris, a Second World War ace.

The first mount was the Grumman F6F-5 Hellcat but just weeks later, transitioned into the all-blue Grumman F8F-1 Bearcat. From that time on, the team was to continually upgrade to the latest jet aircraft and as it did, its fame grew. Even though initially only performing in the US, the international media gave the ensemble plenty of exposure and the team became the greatest recruiting tool for the Navy during the Cold War years.

Having said this, there are equally well-known aerobatic teams in numerous countries worldwide. In North America alone, in addition to the Blue Angels, the US Air Force has the Thunderbirds, currently flying the Lockheed Martin F-16 Fighting Falcon and the Canadians have the Snowbirds flying the Canadair CT-114 Tutor. All three have been active for many years, the Blues being the second oldest aerobatic team in the world; the Patrouille de France, formed in the early 1930s, holding the title of oldest.

So what drove the formation of these national teams? At the end of the Second World War, the civilian populations of the world were weary, they wanted to get on with their lives in peace and experience the 'good life' so fondly created in the movies of the war years.

The massive military organisations of just about every country were quickly dismantled at the end of hostilities; the escalating tensions between the US and Russia were as yet a remote threat to the general public. This was the situation that triggered the formation of the Blue Angels. Both the USAF and US Navy had been hit hard by the drastic military reduction and that meant the loss of highly skilled pilots. The air arm of the US military was going to face a difficult task in replacing them, especially in the new jet age and with the beginnings of the ominous nuclear stand-off with the Soviet Union.

The key to getting the required budget appropriations from Congress was considered as raising public awareness and support, with a public display team being seen as the obvious mechanism to achieve this. That it worked is obvious, the name Blue Angels is known by every American citizen

The two solo Hornets on the Blue Angels have a routine that gets the attention of the crowds. #6, shown here on take-off, will perform what seems like head-on crosses with #5. They pass within inches of each other at a very fast closure rate. **Blue Angels PA via Warren Thompson**

Blue leader Commander Pat Driscoll grabs the arresting cable on the USS *Harry S. Truman*, becoming the first Blue Angel to trap on a carrier. The Blue Angels had already done air shows in Sweden, Finland and many other European countries as early as 1992, flying the F/A-18A and B Hornet. **Blue Angels PA via Warren Thompson**

Left: Four Blue's Hornets head straight down while performing over Seattle's Lake Washington during the 1999 tour. At this time, the team was flying F/A-18Cs and Ds. While performing air shows in major cities, it is easy to draw 100,000 spectators in a single day. **Blue Angels Public Affairs via Warren Thompson**

and the team would eventually draw over 260 million spectators to air shows from coast to coast.

THE EARLY YEARS

Lt Commander Voris looks back on those early days in the mid-1940s when the team was based out of NAS Jacksonville, Florida. "With four short words 'and-up-we-go' spoken in a cadence setting the 4G pull-up schedule, we entered a high hanging vee loop as our opening manoeuvre at the first public appearance of the brand new Blue Angels Demo team. It was a Saturday afternoon on June 15, 1946.

"The occasion was the Southeastern Air Show at Craig Field in Jacksonville, which was over a half century ago. At that time we were flying three glistening blue and Gold Grumman F6F Hellcats and it was to our advantage because the public was well aware of these aeroplanes because they had been the mainstay of our carrier air groups during the war. Looking back to those days, it was obvious that the public's interest in our military was fading and we didn't know it at that time, but we had stumbled on to an idea that was going to help our recruitment for the next 50+ years.

"I was given the responsibility of organising, training and leading the team. Believe me when I tell you... the training was intense! It was our job to demonstrate the precision flying excellence of Navy carrier fighter aviation. By July 1946, we had adopted our new name Blue Angels, and it would be a name that would last through the ages.

"With our team formed up, now the moment of truth was at hand. How would we be received and measured? We were not only representing the team but all of naval aviation. We knew from the start that only the best would be acceptable and second best was not on the cards. We kept this mindset for the duration. On that day, Florida weather was true to that time of year; hot, humid and bumpy. Heat waves were clearly visible shimmering off the blacktop runway.

"Tightening up our straps as the bumping turned to jolting; we pulled into the front side of our opening loop. It would be a 12-minute show and we had to keep it right in front of the crowd to get the full impact. Believe me, it was 12 intense breath holding minutes of grunt, pull, turn and roll. Our Hellcats had been lightened by fuelling only one of the three fuel cells and this increased the aircraft's performance and agility."

After coming out of the loop, the team immediately pulled up into a Cuban Eight followed by a tight Chandelle turn entry into an arcing Vee Roll. A left echelon roll was followed by a 100ft inverted pass, with another Chandelle turn bringing the Hellcats back for a backing left echelon roll and then to a 100ft low altitude inverted pass.

"Going full power, we re-entered with a reverse one-half Cuban Eight, followed by a reverse echelon roll, with the final manoeuvre being a second Vee Roll and a

One of the trademarks for the Blue Angels is the 'F/A-18 Diamond Formation' shown here. The formation is so tight that the wing tips are overlapping, only inches away from the others. **Blue Angels PA via Warren Thompson**

finishing reverse echelon roll to a break for landing. All of our manoeuvres were entered and exited at 100ft of altitude. With the exception of the Vee Roll, we executed all rolls about the axis of each aircraft. This required our #2 and #3 to roll blind for 180° of a 360° roll. Our first public appearance gained us the trophy for the most outstanding performance of the air show."

Word spread quickly about these Navy pilots putting on a spectacular display of aerobatics and as a result, all of the team's air shows in the future would be before huge crowds. This trend has never wavered as the Blues moved from one aircraft type to another.

Starting out with the Grumman F6F Hellcat then the FSF-1 Bearcat, the pilots transitioned into jets in 1949 with the Grumman F9F-2 and F9F-5 Panthers. It should be noted here that in 1952, the team took on two Vought F7U Cutlasses that were originally to be used as a side demonstration to test the feasibility of taking the type on as the main team aircraft.

Due to several factors, it was decided to not use it at all and the Panthers remained in flight It was inevitable that the next move would be to swept wing jets, a move that happened in 1954 with the introduction of the Grumman F9F-8 Cougar. Next on the agenda was acquiring a supersonic aircraft, so in 1957 they began flying the Grumman F11F Tigers which would last until 1969.

These were replaced by the massive and powerful McDonnell Douglas F-4J Phantom II that year. The heavy but impressive Phantom was replaced by the lighter and more manoeuvrable Douglas A-4F Skyhawk in December 1974, the 12-year tenure of this type being celebrated by the four aircraft that hang in the atrium of the National Museum of Naval Aviation at Pensacola today. ➤

AIRCRAFT OF THE BLUE ANGELS

TEAM AEROBATIC AIRCRAFT

Grumman F6F-5 Hellcat	June to August 1946
Grumman F8F-1 Bearcat	August 1946 to 1949
Grumman F9F-2 Panther	1949 to June 1950
Grumman F9F-5 Panther	1951 to end 1954
Grumman F9F-8 Cougar	1955 to mid-season 1957
Grumman F11F-1 Tiger	mid-season 1957 to 1969
McDonnell Douglas F-4J Phantom II	1969 to December 1974
Douglas A-4F Skyhawk	December 1974 to November 1986
McDonnell Douglas F/A-18A and B Hornet	November 1986 to 1992
McDonnell Douglas F/A-18C and D Hornet	1992 to today

TEAM SUPPORT AIRCRAFT

Douglas R4D Skytrain	1949 to 1955
Curtiss RSC Commando	1953
Douglas RSD Skymaster	1956 to 1968
Lockheed C-121 Super Constellation	1969 to 1973
Lockheed KC-130F/T Hercules nicknamed 'Fat Albert'	1970 to today

OTHER TYPES

A North American SNJ Texan was used to simulate a Mitsubishi A6M Zero aircraft in demonstrations during the late 1940s.

A Lockheed T-33 Shooting Star was used as a VIP transport aircraft for the team in the 1950s.

Two Vought F7U Cutlass tailless fighters were flown as a pair demonstration during the 1953 season but plans to introduce it as the team's primary aircraft were cancelled.

The Blues operate with six Hornets as main features in each show. #5 and #6 are the solo features as seen in this tight fly over with one inverted and wing tip to wing tip. **Blue Angels Public Affairs via Warren Thompson**

Commander Pat Driscoll, leader of the Blue Angels in 1999 was the first Blues pilot to land and take off from an aircraft carrier. This view shows him getting ready to catapult off the USS *Harry S. Truman*. The leaders of the team always flies the #1 bird. **Blue Angels Public Affairs via Warren Thompson**

One of the Solo Hornets (number 5) makes a low high-speed pass over the water that was jammed with boats loaded with spectators enjoying the air show. **Boeing via Warren Thompson**

In the same month, the designation of the team was officially changed to become the US Navy Flight Demonstration Squadron. As already mentioned the team transitioned on to the powerful but agile McDonnell Douglas F/A-18A and B in 1986, and has operated the C and D models since 1992.

WHAT IS REQUIRED TO BECOME A BLUE ANGEL?

Since the days of the Second World War, the US Navy has always been blessed with an abundance of skilled pilots. Despite the reductions from the downsizing of the military in late 1945, as far as their airmanship skills were concerned the formation of the Blue Angels maintained the image of excellence to the general public.

There was never any doubt in the eyes of those air show spectators that the pilots they were watching were the elite in a very select fraternity. This is not demonstrated in words, but in what they do in the air, and on the ground. Throughout the years, after every air show performance, the pilots mingle with the crowds, posing for pictures and engaging in conversation, especially with the younger generation as they are the US military's future.

Reporters have written countless times that the greatest asset of the Blues is an ability to relate to the people and this trait is probably the key to the team's unwavering success in over a half century. However, there was a popularity surge when the line-up made the switch to the powerful McDonnell Douglas F/A-18A and B in November 1986, the supersonic Hornet is still the 'king of the hill' with the Blue Angels team as of 2014.

At the time the author was the guest of the team at Pensacola in 1999, the leader was Commander Pat Driscoll USN. The position of team leader is hard won, reached only through a long series of naval aviation credentials and achievements. At the time, he had 4000 total hours of flying time, 930 carrier traps which included cockpit time in the Lockheed S-3A Viking, the Vought A-7A Corsair II as well as the F/A-18 Hornet.

He also made the first carrier trap for a Blue Angels Hornet on the USS *Harry S. Truman*, CVN-75, in 1998. In an interview right after he had become the leader of the Blues, he commented about what it takes to become a Blue Angel. "First of all, you have to pay your dues!" he said.

"There is a basic minimum requirement you must have. At this time, it is 1350 flight hours and a tour in the fleet flying a tactical jet. Our pilots have either flown a tour on a carrier cruise or if they are marines, they must have made a forward deployment. Normally, this means that if they have completed their first fleet tour and are now in a shore tour, they are probably a flight instructor at one of the fleet replacement squadrons in the F/A-18 or the AV-8B Harrier.

"Above all the experience that is required, they have to want to be a Blue Angel. When all criteria have been met, then they must put in an application just like all the others that are on the team, both pilots and enlisted ground crew. All of these applications come into the squadron late in the year. We compile these together and start screening the applications, looking at their total packages. They usually attend some of the air shows and we get to meet them personally. The informal term for this is 'rushing the Blues'.

"It is an excellent opportunity to get to know them on a one-to-one basis and that is equally important for they must have a good personality and have the ability to get along with others in addition to their flying skills. We will spend between 280 and 300 days a year together on the road and that is a lot of time to spend with anyone, especially since we do it as a group. All applicants have the opportunity to come out to some of the air shows and spend time mingling with the team which includes going out and eating meals with us and attending our briefings etc. This, in turn, gives our team a chance to know and evaluate them. Once we have met all applicants, we sit down as a group and select six Navy pilots and three Marine pilots to return for more interviews.

"Each year, only about three pilot slots become available. The final selections are determined only after each member has had quality time with each of the finalists; golf, skiing, dinner, volleyball etc. After this regimen, there is no doubt as to what each

It has been standard procedure for the Blues to do a low-level fly-past when the graduation ceremony is completed at the US Naval Academy. This image speaks for itself. **US Navy via Warren Thompson**

One of the most spectacular images ever taken of the Hornets was done by the Blue Angels over Niagara Falls in New York. They were working a big air show in the area at the time. **Blue Angels Public Affairs via Warren Thompson**

candidate has to offer. The next step is a serious interview with each of the finalists that lasts about one hour. In this closed session, we ask a wide range of questions covering their aviation skills, mistakes they have made and their conduct in social situations. The latter is important because at every air show we perform in, we meet some of the most important people in those communities in addition to the general public and after all we do represent the US Navy and have to put forth a great impression.

"The next step is to sit down and discuss whom we are going to elect. This is very difficult because people who want to become Blue Angels all have outstanding records, so we have to choose from the best of the best."

Once the new pilots and support personnel have been selected for the next season, the real work begins because some of the most difficult flying skills have to be honed and the time to accomplish this is very limited. The entire Blue Angels organisation heads for the desert around El Centro, California, for close to three months where they will fly six days a week and maybe as many as three times per day. This is what is needed to create a superior aerobatic team from the cockpit skill level. The process is demanding but has proven to be the best way to go. By getting away from all distractions, it is easier to focus on developing routines. For the first six weeks of the seclusion, families are not allowed to be with the pilots and support personnel.

Commander Driscoll continued: "It requires two and a half months from the time we start our practice sessions until the first air show. We usually get to El Centro in early January and the first air shows start sometime around mid-March. We usually do our shows on Saturdays and Sundays ➤

The four main Hornets with the Blues move out of the parking area in unison and prepare to start an air show. The crowd in the background is an overflow from the main spectator area. The crowds they drew during the summer months in the 1980s and 1990s were huge. **US Navy via Warren Thompson**

The C-130 Hercules has been a vital part of the demo team since 1970. It goes by the name of 'Fat Albert'. Not only does it transport ground crew and equipment, at many air shows the aircraft also performs its own display. **US Navy via Warren Thompson**

One of the main criteria for any Blue Angels pilot is to have a pleasant personality that relates well to the spectators. Here, Lieutenant David Silkey visits with a few civilian VIPs who were allowed to watch the Blues' final practice run before heading to Moody AFB in Valdosta, Georgia for an air show. This was taken on the ramp at the HQ at NAS Pensacola. **Warren Thompson**

Blue Angel Hornets bank over the crowd in famous four-ship diamond formation. From the ground, it looks like there are only inches separating the aircraft. **Blue Angels PA via Warren Thompson**

This bizarre angle shows just how close the Hornet's wing tips are to each other during their aerial demonstrations. Their records state that over 15 million spectators attended their air shows during the 1999 season. They were flying the C and D model Hornet at that time. **US Navy via Warren Thompson**

Lt Commander R. M. 'Butch' Voris, the founding father of the Blue Angels. poses in the cockpit of his FBF-1 Bearcat on the ramp during the early days of the Blue Angels in late 1946. **R. M. Voris via Warren Thompson**

The first supersonic jet flown by the Blues was the Grumman F-11F-1, brought in about mid-season 1957 and flown until 1969 before the team converted over to the F-4J Phantom II. This was taken over Mount Rushmore during a photo shoot. **Peter Mersky via Warren Thompson**

and return to NAS Pensacola late Sunday afternoon. I think all of our pilots will agree that the greatest satisfaction we get is talking to the kids after the shows. As we are signing autographs for them, we tell each of them that if they want to become a Blue Angel, they have to stay in school, study hard and stay away from drugs and alcohol.

"We have their undivided attention and that is the time to get our point across. We also tell them it would not hurt to get involved in extra-curricular activities and as a bonus if they could get accepted into one of the service academies such as Naval Academy or Air Force Academy it would be a plus. While the latter is not a definite requirement, it puts an emphasis on getting a college education."

MAINTAINING THE BLUES' HORNETS

While the quality of the pilots selected to fly the F/A-18C with the team is among the best, the requirements for the maintainers is just as high. One of the more experienced of these is AME1 Brian DeRitter who was supervisor in quality assurance (maintenance chief). He had been with the Blues for about three years and before that he had logged 11 years with the regular Navy which included cruises on the USS *Constellation* and USS *Kitty Hawk*.

He explained what is expected when they are looking at new members: "Just how tough is it to become a Blue Angel if you are among the enlisted ranks? We look for someone who is technically proficient in their rating with a good speaking ability because we interact with the public more than the pilots do. On the Saturday before the first air show, we arrive at that airbase about 6am and sometimes don't leave until after 9pm. We are close to the crowd the entire time as the pilots usually don't mingle until after they perform.

"As far as someone wanting to join the group, there are procedures and channels that have to be followed. Their commanding officer has to write a letter of recommendation and once your application is in, you are scheduled for an interview. The first day is usually spent talking with people in the organisation and having records reviewed. These go back all the way to Day One. ➤

F/A 18 HORNETS OPERATED BY THE BLUE ANGELS

Bu.No.	Location
160255	On display outside Grenada High School, Mississippi in 2010, painted as a Blue Angels aircraft but did not fly with the team.
161353	Former Blue Angel 1990-91. Retired to National Museum of Naval Aviation and loaned to Naval Air Test and Evaluation Museum, Patuxent, Maryland, on display there since September 1996.
161354	Former Blue Angel aircraft, struck off on October 4, 1999 and cut up to become an F/A-18D flight simulator.
161355	Former Blue Angel. Transferred to NASA as 846, given the civil registration of N846NA in July 2001.
161366	Former Blue Angel. On display at NAS Lemoore, California.
161519	Former Blue Angel. Transferred to NASA as 843, given the civil registration N843NA in July 2001.
161520	Former Blue Angel. Transferred to NASA as 847 in September 1989 and given the civil registration N847NA July 2001.
161521	Blue Angels aircraft transferred to the Aerospace Maintenance and Regeneration Centre (AMARC) at Davis-Monthan AFB in Arizona on May 3, 1995. Currently in storage at NASA Ames Research Centre, Moffett Field, California.
161522	Blue Angel 5, crashed near Brawley, California, during training on February 12, 1987. The pilot successfully ejected.
161523	Former Blue Angel transferred to AMARC on May 3, 1995.
161524	Blue Angel 2 collided with 161973 during training on January 23, 1990, at El Centro, California. Pilot successfully ejected, the second aircraft landed.
161525	Former Blue Angel.
161526	Former Blue Angel.
161527	Former Blue Angel.
161528	Former Blue Angel.
161711	Former Blue Angel 7 in 2009, transferred to AMARC June 29, 2010.
161723	Blue Angel 7 in 2009 and 10, struck off charge 2012.
161726	Blue Angel, now on static display at NAS JRB, New Orleans, Louisiana.
161746	Former Blue Angel, now on display at the St Louis Science Museum, St Louis, Missouri.
161931	Former Blue Angel stored at NAS Pensacola, Florida from 2003.
161932	Blue Angel, crashed on October 28, 1999, during airshow practice at Moody AFB, Georgia, both pilots were killed.
161941	Former Blue Angel now on display as gate guard at NAS Jacksonville, Florida.
161942	Blue Angel 3 and later 4, now on display at USS Lexington Museum, Corpus Christi, Texas.
161943	Blue Angel 7, struck off charge in 2008 and now at the Detroit Science Center, Detroit, Michigan.
161945	Former Blue Angel.
161948	Former Blue Angel 3 now on display at the Valiant Air Command Warbird Museum, Titusville, Florida.
161952	Former Blue Angel at Naval Air Technical Training Centre, NAS Pensacola, Florida in 2004.
161955	Former Blue Angel now on display at the National Museum of Naval Aviation in Pensacola, Florida.
161956	Blue Angel 6 crashed into Gulf of Mexico near Perdido Key, Florida, December 1, 2004. Pilot successfully ejected and was rescued.
161957	Former Blue Angel on display at NAWCTSD Orlando, Florida.
161959	Former Blue Angel 2 then 4 in 2009, in storage at NAS Pensacola, Florida, 2013.

McDonnell Douglas F/A-18A 161942 as Blue Angel 3, this aircraft is now on display at USS Lexington Museum, Corpus Christi, Texas. **Luigino Caliaro**

Bu.No.	Location
161960	Former Blue Angel 6 now on static display at NAS Whiting Field, Florida 2011.
161962	Former Blue Angel struck off charge on July 5, 2000, at Naval Air Technical Training Centre, NAS Pensacola, Florida in 2004.
161963	Former Blue Angel 2. Struck off charge in 2007 now on display at San Diego Air and Space Museum, California.
161964	Former Blue Angel transferred to AMARC as 1A0053 on August 12, 1996, and struck off charge January 8, 2003.
161965	Former Blue Angel transferred to AMARC as 1A0058 January 17, 1997.
161967	Blue Angel 1 in 2002 to 2009, on display at NAS Kingsville, Texas, 2010.
161969	Blue Angel, at Naval Air Technical Training Centre, NAS Pensacola, Florida in 2004.
161973	Blue Angel 1 collided with 161524 on January 23, 1990, landed safely but damaged. Struck off charge in 1994, purchased by Air Capitol Warbirds, registered N118FA on August 5, 2004.
161975	Former Blue Angel now static display at NAS Pensacola, Florida.
161978	Former Blue Angel.
161983	Former Blue Angel now on display at US Naval Academy, Annapolis, Maryland.
161984	Former Blue Angel now on display at Kalamazoo Air Zoo Museum, Michigan.
161985	Former Blue Angel transferred to AMARC as 1A0060 on January 24, 1997.
162411	Blue Angel 5 in October 2009.
162437	Blue Angel 5 in October 2006.
162448	On display at NAF El Centro painted as Blue Angel 1 but not a team aircraft.
162826	Former Blue Angel 3, now on display at the Veteran's Memorial Air Park Museum, Meacham Field Airport, Fort Worth, Texas, 2013.
162897	Blue Angel 6, crashed at MCAS Beaufort, April 21, 2007. The pilot was killed and eight others were injured on the ground.
163093	Former Blue Angel 6 in 2009, transferred to AMARC in December 2012, now on display at the Pima Air Museum since July 31, 2013.
163105	Blue Angel 6 in October 2006.
163106	Blue Angel 2 in June 2010.
163130	Blue Angel 5 in July 2007, now on display at NAS Corpus Christi, Texas.
163435	Blue Angel 6 in June 2010.
163442	Blue Angel 3 in 2011.
163451	Blue Angels in 2011.
163455	Blue Angels in 2011.
163464	Blue Angels in 2011.
163468	Blue Angels in 2011.
163498	Blue Angel 5 in 2011.
163705	Blue Angel 1 in June 2010.
163765	Blue Angels in 2011.
163768	Blue Angels in 2011.

This was a new F/A-18B two-seater assigned to the Blue Angels in 1989. It carried the number 7 on the stabiliser and was probably the one that two of the Blue Angels were killed in on October 28, 1999, when it went into the trees on approach to Moody AFB, Georgia. The team was coming in for an air show that weekend. **Peter Mersky via Warren Thompson**

The solo pair, Blue Angel 5 and 6 appear between manoeuvres from the four-ship element in a variety of passes, including several high speed, low level and very close crosses. **Luigino Caliaro**

The original four Blue Angels pilots pose by one of their F8F-1 Bearcats soon after the team formed up in the summer of 1946. They would fly the Bearcat until 1949 when they would switch over to the Grumman F9F Panther. **R. M. Voris via Warren Thompson**

The first supersonic jet to be flown by the Blue Angels was the Grumman F11F-1 Tiger shown here during an air show in the early 1960s. **Peter Mersky via Warren Thompson**

The Blue Angels formed a vital part of the 100th Anniversary of Naval Aviation celebrations, taking part in the massive aerial commemoration at San Diego in 2011. **Keith Draycott**

"All of the candidates are made aware of the fast-paced tempo and obligations. We have to go wherever the team goes, but we have enough specialists to allow us to alternate road trips with our counterparts which means we are not on the road as much as the pilots. In 1998, I was gone for 150 days and this time away puts a hardship on families, but the commitment is understood on the front end so there are no surprises. A lot of the workload depends in how well the jets are behaving.

"Some days we are out on the line around the clock and on others we are through in six hours. But you have to realise that with the amount of stress put on our Hornets, our work has to be perfect. We are assisted by the fact that McDonnell Douglas has done a superb job in designing and building the F/A-18.

"We perform a lot of preventive maintenance. We do inspections based on dates, like every seven days, every 14 days etc. We make certain inspections, where every 30 flight hours we go in and check a specific item. Everything is scheduled down to the hour and that prevents potential problems. One of the things we do every morning before the demo flights is to go out and start all the Hornets. We do meticulous checks on the systems to ensure that everything is working perfectly when the pilots climb into the cockpit. Normally, our maintenance tours with the Blues last three years which always gives us two-thirds of our experienced personnel on hand to train the new ones coming in."

THE F/A-18 IN THE DISPLAY

The tough and reliable F/A-18 is the perfect machine for the demanding air display regimen. The display routine is built around the strengths of the aircraft and the high skills of the pilots. Usually, Angels 1 through 4 perform manoeuvres in the team's famous overlapping Diamond Formation while the two Solo birds, Angels 5 and 6, take centre stage in between the manoeuvres of the main group. This keeps an element of the line-up in front of the crowd throughout the display. The main four Hornets, in tight formation at very low altitudes usually fly at speeds of around 400mph, performing a routine involving tight formation loops and barrel rolls.

The Solo pair fly a very different display comprising high and low speed passes, slow rolls and demonstrations of the tight turning radius of the Hornet. The highest speed used during a performance is about 700mph, slightly below the speed of sound. The slowest pass is flown at about 120mph. The display is practiced in three versions, high, low and flat, each of these aimed at allowing a display to be flown regardless of the prevailing weather conditions.

There are only a few changes to the team's aircraft from the standard F/A-18Cs. The nose mounted cannon is replaced by the oil tank required to produce the display smoke and the stick is fitted with a spring tension system that enables extremely

The impression that the Blue Angels are overlapping is not an illusion, this is precision flying at its best. Note that the #4 aircraft at the rear of the formation is an F/A-18D two-seater. **Luigino Caliaro**

Looking down the four-ship element in a left turn in echelon formation from the back seat of Blue Angel 4. **Luigino Caliaro**

Absolute precision. The Blue Angels at their finest. **Luigino Caliaro**

A view of the underside of Blue Angel 1 as the four ship pulls over the top of a loop. **Luigino Caliaro**

precise control.

The pilots do not wear G-suits, despite the stresses incurred in the displays, instead they rely on building up G-tolerance through muscle control to control the flow of blood to and from the brain.

The military G-suits cannot be worn because the constant inflating and deflating of the suits would interfere with the movement of the control stick. Other than these two changes, the F/A-18s are combat ready aircraft in all other respects.

On November 8, 1986, the Blue Angels first received the F/A-18A and B Hornet, the single two seat aircraft flying as Angel 7, piloted to display venues by the team's commentator. Aside from its use as a spare aircraft, Angel 7 can also be used to give demonstration flights to VIP guests of the team, as well as providing the perfect camera platform.

The F/A-18C and D aircraft were introduced in 1992, performing full seasons with the team until 2013, when the majority of that year's displays were cancelled as part of the defence budget sequestration. In September 2013, the 2014 schedule of Blue Angels displays was released which will see the team again displaying a full season throughout North America. The F/A-18 had served the Navy and the Blue Angels extremely well and there is no end in sight for this magnificent fighter.

■ Words: *Warren E. Thompson*

Developing the breed

The F/A-18 C and D

The introduction of the Hornet into US Navy and Marine Corps service at the beginning of the 1980s occurred in the middle of a revolution in computer technology and systems capabilities. So much new equipment lent itself to integration into the aircraft that two entirely new models of Hornet evolved and entered the production lines.

The 1980s were a time of enormous advances in computer technology and not just in the fields of business and defence. The first models of home computers were being introduced, a market that would drive ever smaller and more powerful systems development.

On top of improved data processing speeds and capacities, sensors and targeting systems were moving forward at a tremendous pace. The early laser designators and spot trackers were giving way to a third generation of more powerful systems that could keep track of a target even while the aircraft was manoeuvring.

The first forward looking infrared sensors had developed into reliable and more complex systems, many operating alongside or fully incorporating thermal imaging and low light camera technology to literally turn night into day. The advent of night vision goggles and upgraded displays that were compatible with them allowed aircrew to operate with almost complete freedom and accuracy regardless of the time of day or the weather.

The F/A-18As and Bs in service at this time were establishing an excellent reputation, particularly for the reliability and ease of maintenance of their engines, airframes and avionics. One of the factors that this growing reputation was based on was the fact it was the first naval aircraft built around a digital multiplex avionics bus.

This allowed individual systems within the electronics and avionics to be upgraded easily, with the option of changing software or hardware becoming a relatively straightforward task. However, given the speed of development in the computer and avionics field, even this facility could not cope with the volume of improvements and a new technology core was developed for the F/A-18 that would not only take advantage of the new systems, but would also allow a new generation of weapons to be carried.

The development of the upgraded system began in mid-1987 and was based around much more powerful and capable mission computers and an improved standard databus of higher capacity. The AN/APG-65 I-band radar was significantly upgraded, with new air-to-air and air-to-ground modes added to its capabilities, including an improved track while scan mode, a synthetic aperture ground mapping mode and fixed and moving ground target tracking and sea surface search.

These improvements allowed the carriage of the new AIM-120 AMRAAM air-to-air missile and the AGM-65F Maverick and AGM-84 Harpoon air-to-surface missiles. To improve the F/A-18's survivability in a hostile air defence environment, the AN/APQ-165 Airborne Self Protection Jammer (ASPJ) was evaluated and eventually introduced in small numbers in the early 1990s.

These upgrades expanded the flexibility of the F/A-18 system still further, allowing as they did the faster and simpler integration of new avionics software and hardware into the aircraft. Two more

A fine shot of the Captain Jeffrey Davis, Carrier Air Group Commander aboard the USS *George H. W. Bush*, landing in his F/A-18C of VFA-15, the Valions. Note the four antennae and bulges at the top of the fins as opposed to the three on the F/A-18A and B, one of the few recognition points between the early and late aircraft. **Luigino Caliaro**

The cockpit of a McDonnell Douglas F/A-18C showing the improved radar and multifunction displays. **US Navy**

The Loral AN/AAS-38A NITE Hawk forward looking infrared targeting pod is carried on the port fuselage station of an F/A-18C. This version of the pod introduced a laser designator allowing the Hornet to mark its own targets. **Frostbite36**

The AN/APG-73 radar began to be fitted to the F/A-18Cs on the production line in 1992. This is a tremendously capable system with far greater memory capacity and date throughput than the earlier -65 version. **US Navy**

changes were made in the cockpit, the first being that the ejection seat was standardised on the Martin Baker NACES (Navy Aircrew Common Ejection Seat) which replaced the Mk 10S in the F/A-18A and B.

Secondly, a flight incident recording and monitoring system was installed to allow data on stress and failure incidents to be collected. The improved aircraft was designated F/A-18C, the first one being 163427, a Block 23 production aircraft that first flew September 3, 1987, in the hands of test pilot Glenn Larson.

The C model Hornet was to be upgraded still further while in production, the first of these being to improve the night attack capabilities of the aircraft after 137 of the original C model had been built. Beginning in October 1989, the F/A-18Cs were fitted with upgraded sensors, the Hughes AN/AAN-50 Thermal Imaging Navigation Set (TINS) and an improved version of the Loral AN/AAS-38 NITE Hawk forward looking infrared targeting pod.

This was used in conjunction with the ASQ-173 laser detector and tracker camera pod, which sends target location information to the mission computer and cockpit displays.

Complementing these were a new raster Head Up Display and two new full colour multifunction displays with a colour moving map function. These new displays and the whole cockpit were also made compatible with night vision goggles enabling the pilots to fly and fight the aircraft in complete darkness.

In August 1991, the Kuwaiti Air Force ordered the F/A-18C, but with the General Electric F404-GE-402 version of the turbofan which produced 17,700lb (8030kg) of thrust.

These engines were introduced into the production line for the US Navy and Marine Corps Hornets in April 1992. Also that ➤

A close-up of the nose of a VMFA(AW)-332 ATARS equipped F/A-18D(RC) shows the forward clear window for the LAEO (Low Altitude Electro Optical) and MAEO (Medium Altitude Electro Optical) sensors and the rear orange tinted opening for the IRLS (Infra Red Line Scan). Note also the closed cannon ports. **US Navy**

A side view of an ATARS equipped F/A-18D(RC) of VMFA(AW)-224. **Keith Draycott**

year, the AN/APG-65 radar began to be replaced with the -73 model. The radar had been redesigned with a greater memory capacity and far higher data handling capability, using modules and software from the AN/APG-70 radar fitted to the F-15 Eagle.

This reduced the costs of the upgrade and the subsequent maintenance considerably, while giving the new radar enhanced mapping and targeting modes as well as improved reliability.

Many of the F/A-18C's upgrades, including the radar, began to be retrofitted to the existing F/A-18A fleet in 1992, these being designated F/A-18A+ once the work was complete.

From 1993 onwards, the F/A-18Cs were also capable of carrying the improved version of the AN/AAS-38 targeting pod, the AN/AAS-38A with a built-in laser designator that allowed it to mark its own targets. In 1996, this was improved still further with the AN/AAS-38B which featured an auto-tracking capability to stay locked on to a designated target even if the aircraft was manoeuvring. This reliable system only began to be phased out of service in 2008, when the introduction of the ASQ-228 ATFLIR pod slowly began to replace them across the Hornet fleet.

As well as these upgrades, the F/A-18Cs also received the new Litton AN/ANS-39 Inertial Navigation System in 1991, which was complemented by the addition of a GPS receiver in 1995, and the Identification Friend or Foe (IFF) system was upgraded in 1997. A total of 466 F/A-18Cs were built for the US Navy and Marine Corps, with more going to Kuwait, Finland, Switzerland and Malaysia before production ended in 1999.

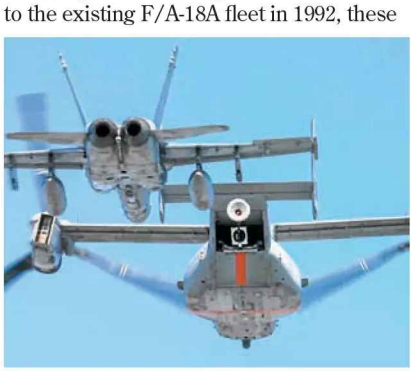
The F/A-18C upgrades were also applied to the two-seat aircraft, the F/A-18B becoming the F/A-18D through the same process. Like the F/A-18C, the first 31 F/A-18Ds off the production line were only the first stage of the improvement process, the remaining 130 built for the US Navy and Marine Corps featured the night attack improvements and other upgrades as production continued.

Unlike the F/A-18B, the F/A-18D is not only configurable as a trainer. The stick and throttle in the rear cockpit can be removed and a pair of fixed hand controllers fitted to allow the rear crewman to operate the sensors and deploy the weapons. The two-seat aircraft excels in the night attack role, as the high workload of these missions is more effectively split between the two crew members.

Also in this configuration, the F/A-18Ds are often used as Forward Air Controllers (Airborne) (FAC(A)s) by the US Marine Corps, acquiring, tracking and designating targets for other aircraft with lasers or smoke rockets. The last F/A-18D was delivered in 2000, the upgrades the Hornet has received ensuring it will remain in service long into the 2020s until it is replaced by the Lockheed Martin F-35B in the US Marine Corps and the F-35C in the US Navy.

One other development of the F/A-18D must be mentioned, as it represents the third attempt to produce a photo-reconnaissance version of the Hornet. As already mentioned, in 1984 the F/A-18(R) had been modified from a single F/A-18A and tested with a camera and sensor pack in the nose. This was followed by the RF-18 concept for a dedicated reconnaissance Hornet, which although it generated a great deal of interest from the US Marine Corps, which needed to replace its RF-4B Phantom IIs, fell victim to the defence cuts of the time.

In the early 1990s, the USAF was developing the Advanced Tactical Airborne Reconnaissance System (ATARS) for the F-16, which the US Marine Corps selected to fit to the F/A-18D. Even though the USAF withdrew from the ATARS programme in June 1993, after a US Navy review, the Marine Corps took it over in January 1994. A drop tank was modified with the ATARS mounted in it,



Flexibility is the key to air power, and this is about as flexible as it is possible to get. The highly adaptable F/A-18C is seen here positioning on a refuelling trial from a V-22 Osprey tilt rotor transport, one of the most flexible transport aircraft in the world. **US Navy**

A side view of a McDonnell Douglas F/A-18C Hornet of VFA-204, the River Rattlers. **Keith Draycott**

the first flight trials taking place using the first production F/A-18D. However, the presence of the pod reduced the attack capability of the carrying aircraft, so a more elegant solution was proposed.

Using the same pallet under the nose idea as on the F/A-18(R) in 1984, the ATARS was fitted in place of the M-61 20mm cannon. ATARS has three sensors, the LAEO (Low Altitude Electro Optical), the MAEO (Medium Altitude Electro Optical) and the IRLS (Infra Red Line Scan). The LAEO and IRLS are primarily used for altitudes of between 200ft and 3000ft, while the MAEO is used between 3000ft and 20,000ft.

The LAEO has a wide field of view at 138°, while the MAEO can only scan 22° but it can slew from horizon to horizon. The IRLS on the other hand can operate in either a wide mode of 140° or a narrow one of 70°. Data captured by the sensors was originally recorded on two digital tape recorders which have now been replaced by far more reliable digital recorders.

The EO and IRLS data are not the only things recorded. The AN/APG-73 radar in synthetic aperture mode provides highly detailed mapping data which is also fed into the system. The data can be stored in the aircraft for processing after landing, or transmitted almost in real time to any properly equipped ground station.

In November 1995, McDonnell Douglas was awarded a contract to integrate ATARS into the F/A-18D which was followed by the purchase of four ATARS suites for trials and evaluation in December 1996. In March 1998, approval was given for the purchase of six more operational ATARS and four datalink pods, with a further increase in the programme approved the following year.

Even though the evaluation and testing was not complete, in February 2000 the first operational use of ATARS equipped aircraft occurred when VMFA(AW)-332 based at MCAS Beaufort deployed to Hungary to support Operation Allied Force. The ATARS can be removed from the nose and the cannon replaced in a matter of hours, but this is rarely done, as the aircraft have proved supremely useful in the reconnaissance role.

The avionics and radar upgrades to the F/A-18C and D enabled it to carry the AIM-120 AMRAAM. Here an aircraft of the US Navy's test and evaluation squadron VX-4 is seen carrying 10 of them, an unlikely load, but an impressive ability. **US Navy**

The ability of the reconnaissance aircraft to join the strike formation and transmit its data almost in real time means the reconnaissance F/A-18D is able to give local theatre commanders information they can act on immediately if required. Since the ATARS equipped Hornet is part of the strike mission, the aircraft is not exposed to enemy defences in the same way previous reconnaissance aircraft were, making lone runs over targets before and after a strike. The aircraft modified to be able to carry the ATARS are known as F/A-18D (RC) s for reconnaissance capability.

What is perhaps most interesting about the progression from the early Hornets to the F/A-18C and D is that there were few changes made to the basic aircraft. The designers had got the Hornet right in terms of structure, handling and reliability, facets that were to endear the aircraft to air and ground crews alike.

The aircraft was proving tremendously flexible, a real force multiplier for the US Navy and Marine Corps as it could quickly be configured to any required role and, unlike many jacks of all trades, was an excellent performer in all of them. The cost of maintaining the previous mixture of aircraft types had proved almost prohibitively expensive. The Hornet solved that budgetary issue at a stroke, yet allowed a sufficiently sizeable fleet to be maintained to support US interests around the globe. The little fighter was proving to be a force multiplier in far more ways than one.

■ Words: *Tim Callaway* ➤

Captain F. O. Pawlowski, Carrier Air Group Commander aboard the USS *Harry S. Truman*. lands back aboard carrying an LGB and the AN/ AAS-38A pod visible on the port weapons stations of his VFA-37 F/A-18C. The ability of the F/A-18 to return and land safely with ordnance was a first for the US Navy. **Luigino Caliaro**

The first Hornets over Iraq

The F/A-18 in Desert Storm

The air campaign of the 1991 Gulf War began on January 17, 1991, with an extensive bombing campaign aimed at achieving air superiority prior to the beginning of the coalition forces' liberation of Kuwait. Nine US Navy and seven US Marine Corps F/A-18 units played a significant part in the conflict.

August 2, 1990, Iraq began the invasion of neighbouring Kuwait, the first action of the conflict being the bombing of the capital, Kuwait City. Iraq's leader, Saddam Hussein, had accused Kuwait of what was essentially economic warfare in two forms.

Firstly, Iraq considered that by exceeding its Organization of the Petroleum Exporting Countries (OPEC) production quotas, Kuwait was driving the barrel price of oil down, causing a reduction by $8 to $10 a barrel and costing Iraq $7 billion a year. Iraq also claimed that Kuwait was 'slant drilling' under the border and into its Rumaila oil field.

The tension between the two countries had built up rapidly due to these and a number of other factors, tension that had been largely unnoticed in Europe and the US because of the speed of the collapse of the USSR and Warsaw Pact. Beginning at midnight on August 2, armoured units of the Iraqi Army, using routes prepared by commandos who had infiltrated Kuwait earlier in the evening, made a two-pronged attack against Kuwait City and the southern half of the country.

After 12 hours of intense fighting, all resistance ceased and the Kuwaiti Royal family had escaped to Saudi Arabia. This further heightened the tension between Iraq and its southern neighbour, Saudi Arabia becoming the next target of Iraqi rhetoric. The US began moving forces immediately to deter further aggression and bolster Saudi defences, an F-15 and F-16 wing along with the first two carrier groups being operational in the Red Sea and the Persian Gulf by August 5.

The United Nations Security Council (UNSC) demanded an immediate withdrawal from Kuwait, initially instigating economic sanctions against Iraq then authorising a naval blockade to enforce them. The UNSC later passed Resolution 678 on November 29, 1990, giving Iraq until

An element of Hornets from CAW-8 closed in to each other for a photo op. They were returning to the carrier after a mission over Iraq in early February 1991. **US Navy via Warren Thompson**

Two F/A-18As loaded with ordnance prepare to fly a strike against Iraqi military positions with an F-14 Tomcat as escort. They were assigned to Carrier Air Wing-8 on the USS *Theodore Roosevelt* during Desert Storm. **US Navy via Warren Thompson**

January 15, 1991, to remove its forces from Kuwait or they would be forced to do so.

The first US Navy Carrier Battle Group (CVBG) to arrive in as part of the Battle Force Red Sea was the USS *Dwight D. Eisenhower* (CVN-69) on August 5, 1990. The USS *Saratoga* (CV-60) arrived in support on August 22 and was to remain until March 11.

The USS *John F. Kennedy* (CV-67) relieved the *Dwight D. Eisenhower* as the Mediterranean carrier on September 4, arriving in the Red Sea on September 15, becoming the flagship of the force and remaining on the deployment until the cease fire on February 27, 1991. Last to arrive was the USS *America* (CV-66) on January 16, conducting operations there until transiting to the Persian Gulf on February 14, becoming the fourth carrier of Battle Force Zulu.

The first CVBG to arrive in the Persian Gulf on August 5, 1990, was that of the USS *Independence* (CV-62). On November 1, the USS *Midway* (CV-41) relieved the Independence, and was to stay on station until March 11, 1991.

Similarly, the USS *Ranger* (CV-61), which had sailed from San Diego on December 8, joined the Battle Force and was also to remain in theatre until the end of the conflict. The final carrier in Battle Force Zulu was the USS *Theodore Roosevelt* (CVN-71), which arrived on January 16, 1991. ➤

Lieutenant Commander Michael Harrison poses by his Hornet prior to another mission over Iraq. The USS *Theodore Roosevelt* began its combat cruise on December 28, 1990, where they joined five other Carrier Battle Groups that would be in position when the war started. **Mike Harrison via Warren Thompson**

One of the deadliest weapons in the Hornet's arsenal is the AGM-84E. It is referred to as the SLAM (Standoff Land Attack Missile). It is also a formidable anti-shipping missile, weighing in at 1366lb and is over 14ft long. **Mike Harrison via Warren Thompson**

With the jet blast barrier up, one of the F/A-18A's gets hooked up to the catapult loaded for a mission during Desert Storm. **Mike Harrison via Warren Thompson**

From altitude, the terrain over parts of Iraq was beautiful. Lt Commander Mike Harrison is working in a two-ship in search of targets. **Mike Harrison via Warren Thompson**

One of VFA-87's Hornets waits for the ordnance crews to get it loaded for a mission. The large external fuel tanks are in place to enable it to roam over Iraq in search of targets and also loiter to provide close air support to the troops. **CVW-8 via Warren Thompson**

The six US Navy Carrier Air Wings (CVWs) deployed during the operational period of the Gulf War included 89 F/A-18 Hornets in nine Squadrons. The USS *Midway* had VFA-151, VFA-192 and VFA-195 on board, all operating the F/A-18A. Also flying the earlier type of Hornet were VFA-15 and VFA-87 of CWV-8 on board the USS *Theodore Roosevelt*. As part of CVW-17, the F/A-18C Hornets of VFA-81 and VFA-83 were embarked aboard the USS *Saratoga*. Lastly, CVW-1 with the F/A-18Cs of VFA-82 and VFA-86 operated from the USS *America*.

Aside from the US Navy F/A-18s, 18 CF-18s of the Royal Canadian Air Force were deployed to Doha in Qatar, arriving on October 6, 1990. The initial deployment was from 409 Squadron, the crews being rotated with those of 439 Squadron in December.

Lastly, 84 ground-based US Marine Corps Hornets were based at Shaikh Isa Air Base in Bahrain. The first to be deployed were the F/A-18Cs of VMFA-235 and the F/A-18As of VMFA-314 on August 20, followed by two more F/A-18A units, VMFA-333 and VMFA-451 the following day on August 21. This considerable force was supplemented by the F/A-18Cs of VMFA-212 and VMFA-232 during January, as well

A Hornet from VFA-87, weapons racks empty, moves off the coast of Kuwait after a mission in search of Iraqi armour. They were assigned to Carrier Air Wing-8 that was flying the F/A-18A. **Mike Harrison via Warren Thompson**

Loaded with ordnance, this VFA-87 Hornet is penetrating deep into Iraq in search of enemy equipment being moved. The roads in this area were few and far between. **Mike Harrison via Warren Thompson**

One of the *Roosevelt's* Hornets traps after a successful mission over Kuwait. It had expended all of its ordnance probably working with a forward air controller in 1991 during Desert Storm. **Mike Harrison via Warren Thompson**

One Hornet has just been catapulted and the steam is still hovering over the deck as the barrier has been immediately retracted allowing another fully loaded F/A-18A to move into position to be hooked up. Both cats were working as fast as possible to get the strike group airborne. **Mike Harrison via Warren Thompson**

as the brand-new all-weather F/A-18Ds of VMFA(AW)-121.

Aside from strike missions aimed at crippling the Iraqi army, air force and command structure, the F/A-18 units flew Suppression of Enemy Air Defence (SEAD) and Close Air Support missions (CAS), as well as Combat Air Patrols (CAPs) with a wide variety of ordnance. On the first night of operations, two F/A-18Cs of VFA-81 were en route to attack an airfield when they were intercepted by a pair of Iraqi MiG-21s.

Lieutenant Commander Mark Fox in 163508 and Lieutenant Nick Mongillo in 163502 successfully engaged the fighters, shooting both down with AIM-9 Sidewinder infrared seeking missiles. The first night also witnessed the first combat casualty for the deployed US forces, when one of the F/A-18Cs of VFA-81 from the USS *Saratoga* was shot down about 100 miles west of Baghdad.

The flight of two F/A-18Cs were operating at 28,000ft when they were ➤

Lt Commander Mike 'Rude' Harrison poses by an AGM-62 Walleye. It was a formidable air-to-ground weapon with uncanny accuracy produced by Martin Marietta. The F/A-18 was a perfect delivery platform for it against any Iraqi ground targets. **Mike Harrison via Warren Thompson**

"THE SIX US NAVY CARRIER AIR WINGS (CVWS) DEPLOYED DURING THE OPERATIONAL PERIOD OF THE GULF WAR INCLUDED 89 F/A-18 HORNETS IN NINE SQUADRONS. VFA-15, VFA-87, VFA-151, VFA-192 AND VFA-195 WERE ALL OPERATING THE F/A-18A. VFA-81 AND VFA-83 WERE EMBARKED ABOARD THE USS *SARATOGA* AND VFA-82 AND VFA-86 OPERATED FROM THE USS *AMERICA*, ALL FLYING THE F/A-18C."

Returning from a lengthy mission, a Hornet successfully snares the cable as it traps on the deck of the USS *Theodore Roosevelt* in mid-February 1991. One of the air wing's electronic warfare EA-6B Prowlers is seen parked on the edge of the deck. **Mike Harrison via Warren Thompson**

engaged by two MiG-25s of the Iraqi 84th Squadron.

Lieutenant Zuhair Dawood fired a radar guided R-40RD missile at Lieutenant Commander Scott 'Spike' Speicher's aircraft, which struck the Hornet head on. Speicher was unable to eject and his body was found by nomadic Bedouins and buried in the desert. Tragically, his death was not confirmed until the burial site was discovered by US Marines in 2009, bringing to an end 18 years of speculation that he was a prisoner in Iraq.

The images and captions in this article have been kindly supplied by our regular contributor, the archivist and aviation historian Warren E. Thompson. They feature the USS *Theodore Roosevelt*, which had VFA-15 and VFA-87 onboard, along with several other squadrons using different aircraft, including some of the 92 Grumman F-14 Tomcats and 95 Grumman A-6A Intruders also used in Desert Storm by the US Navy.

These images are intended as a montage to show how busy and professional the deck crews were in keeping the aircraft ready for the next missions throughout the conflict. CVW-8 flew over 4200 sorties, more than any other carrier, and dropped 4,800,000lb of ordnance during that brief war.

■ Words: *Warren E. Thompson and Tim Callaway*

The view from the back seat is impressive. This F/A-18B is refuelling from the tanker; the squadron is unknown. **Warren Thompson**

An unidentified Hornet moves in close over enemy territory. It is armed with HARM missiles. **Warren Thompson**

The plane captains and ordnance personnel were critical assets that kept the air wing's aircraft in the air. This plane captain poses by what appears to be an AGM-65 missile that his Hornet will carry against Iraqi targets during Desert Storm. **Mike Harrison via Warren Thompson**

The USS *Theodore Roosevelt* makes its way slowly through the Suez Canal enroute to its battle station in the Persian Gulf. Carrier Air Wing 8's aircraft are shown on the deck with an F-14 Tomcat hooked up to the cat in case of trouble. The wing's Hornets are positioned on the forward deck. **US Navy via Warren Thompson**

A returning Hornet prepares to snare the second arresting cable for a perfect trap. It was probably a successful mission because all of its ordnance was dropped and its long-range external tanks are intact. **Mike Harrison via Warren Thompson**

A trailing F/A-18 lines up the lead Hornet in his windscreen. **Warren Thompson**

Lt Commander Mike Harrison takes time off between missions from a perch overlooking the jammed flight deck. His squadron's F/A-18A's are lined up on the starboard side of the flight deck. He and the rest of the air group were deployed for a total of 189 days, returning to Norfolk on June 28, 1991. **Mike Harrison via Warren Thompson**

F-18 operations over Iraq

Operation Southern Watch and Operation Iraqi Freedom

Between 1992 and 2003, units from Allied air forces flew protective air patrols over northern and southern Iraq to protect the populations of those regions. Known as Operation Northern and Southern Watch, these culminated in 2003 with Operation Iraqi Freedom, the second war in the region, and the second time the F/A-18 would be deployed operationally in Iraqi skies.

Five F/A-18C Hornets assigned to Strike Fighter Squadron Twenty Five (VFA 25) aboard the USS *Abraham Lincoln* (CVN 72) in support of Operation Southern Watch. Note the air-to-air ordinance including wingtip AIM-9M Sidewinder Missiles and the larger AIM-7M missiles hanging from the inner wing pylons. **US Navy**

In the Arabian Gulf, just three days prior to the First Tactical Air Strikes of Operation Iraqi Freedom. An F/A-1 BE Super Hornet assigned to VFA-115 is prepared for a catapult launch from the aircraft carrier USS *Abraham Lincoln* (CVN 72). Note the four wing drop tanks as well as the centre line buddy fuel tank used for air-to-air refuelling that the larger version of the Hornet can carry. **US Navy**

An F/A-18C Hornet assigned to the Kestrels of Strike Fighter Squadron One Three Seven (VFA-137) launches from the aircraft carrier USS *Constellation*, during Operation Southern Watch (OSW). **US Navy**

An F/A-18C Hornet assigned to Marine Fighter Attack Squadron (VMFA) 251, makes its final approach back to the USS *George Washington* (CVN-73) after patrolling the no-fly zone in Operation Southern Watch. Note the AGM-88 High-Speed Anti-radiation Missiles (HARMs) under each wing in addition to the AIM-9M Sidewinder short-range air-to-air missiles mounted on each wing tip. The AGM-88 HARM is an air-to-surface tactical missile designed to seek and destroy enemy air defence radar systems. **US Navy**

Arabian Gulf, March 13, 2003 – aviation ordnancemen aboard the USS *Abraham Lincoln* inspect Joint Stand Off Weapons (JSOWs) prior to loading them on to aircraft. The JSOW, in addition to the JDAM, were some of the most used precision-guided munitions deployed by F/A-18 Hornets during Operation Iraqi Freedom. **US Navy**

Operation Southern Watch (OSW) created a no-fly zone in August 1992, preventing Iraqi forces from flying military aircraft or helicopters south of the 32nd parallel. In 1996, this was adjusted to restricting flights south of the 33rd parallel.

Together with Operation Northern Watch, which prevented Iraqi military aircraft from flying north of the 36th parallel, these efforts were meant to protect Shiite populations in southern Iraq and the Kurdish population in northern Iraq from further indiscriminate attacks by Iraqi forces.

To implement this task mandated by the United Nations, JTF-SWA Joint Task Force Southwest Asia) was formed, consisting of US, British, French, and Saudi Arabian Units. Under this command structure of JTFSWA, the US Navy maintained a carrier battle group that was assigned for three to four months of a standard six-month cruise to OSW. Spearheading the Navy effort were carrier-based F/A-18 Hornet units from the US Navy and US Marine Corps.

In 1993, Commander Russ Bartlett flew missions off the deck of USS *Independence* with the US Navy F/A-18 Squadron, VFA-195, during OSW. He recounted his experience: "The orders would come the night before in the ATO (Air Tasking Order). Our intelligence people in CVIC, the Aircraft Carrier Intelligence Center would find our specific mission orders from the ATO. From CVIC, we would get our call signs, information about our assigned air refuelling tanker, our assigned time on station, and all other necessary information for our mission."

On the day of the launch, after completing mission briefing, Hornet pilots proceeded to their jets 45 minutes prior to launching. Fuelling and armaments were secure by this time. Typical configurations for air-to-air missions included AIM-9M Sidewinder and AIM-7 Sparrow III missiles, then, during the later period of OSW, AIM-120C AMRAAM missiles.

On strike missions assigned to preplanned ground targets as part of a Response Option (RO) mission, air-ground ordinance included unguided munitions such as Mk.82 1000lb (454kg) bombs, precision guided munitions such as laser-guided bombs, Joint Direct Attack Munitions ODAMs), or anti-radiation AGM-88 missiles. Invariably, the F/A-18s were also loaded with the Forward-Looking Infra-Red (FLIR) Nite HAWK AAS-28B targeting pod.

Pre-flight checks were completed by pilots on deck within 10 to 15 minutes, before they climbed aboard their aircraft. Thirty minutes prior to launch, the 'air boss' in charge of aircraft operations, would order the pilots to start engines. After a quick check of systems, the Hornets were unchained and marshalled to one of the four catapults for the launch.

Commander Bartlett explained the composition of the air packages of OSW: "Normally we launched in two-ship sections. Occasionally, the fighter squadron or carrier air wing launched a 4-ship division, often each two-ship section would be assigned to a different combat air patrol or geographic location."

After launch from the aircraft carrier, the Hornet pilot located the duty tanker using the Hornet's APG-73 radar, instead of radio communications. After he located the tanker, the pilot positioned the Hornet in the line of aircraft formating off the left wing of the tanker, and waited for his turn to refuel.

After refuelling, the pilot positioned his aircraft off the right wing of the tanker, until his assigned time in the no-fly zone, or 'box' as it was called by the aircrew.

While on combat air patrol station, the Hornet pilots were in constant communication with air traffic control which included an orbiting E-2 or E-3 AWACS in addition to land-based and sea-based assets in the region. ➤

Two F/A-18C Hornets from the Strike Fighter Squadron One Three One (VFA-131) 'Wildcats' patrol the skies over the Arabian Gulf, March 25, 1996, as part of Operation Southern Watch. **US Navy**

Commander Bartlett outlined the typical combat air patrol sortie: "As a two-ship section at our combat air patrol (CAP) station, my wingman and I set up counter-rotating orbits, so that one aircraft would have its radar searching south, while the other aircraft searched north towards Baghdad. That way, we maximized our sensor coverage.

"Occasionally, AWACS pointed out a potential bandit, as the Iraqi Air Force aircraft operated within their airspace on exercise."

After completing the mission, the CAP package then flew 'feet wet' back over the Northern Arabian Gulf to execute refuelling with another air tanker. The aircraft topped off the tanks approximately 500lb above the amount of fuel required to land aboard the ship. A typical F-18 mission during OSW lasted four to five hours.

Commander Bartlett summarized his experience with OSW: "While the majority of combat air patrol missions with Operation Southern Watch were uneventful, they allowed air crew to test and practice using their aircraft sensors. We always carried a FLIR pod so that in addition to our air-to-air radar, we could also monitor the ground with our sensors."

OPERATION DESERT FOX

On December 16, 1998, during Operation Desert Fox, the tempo of strikes increased, as the carriers USS *Enterprise* (CVN-65) and USS *Carl Vinson* (CVN-70) launched more than 400 combat sorties, targeting Iraqi anti-aircraft positions and command and control positions.

From 1998 to the beginning of Operation Iraqi Freedom (OIF), the pace of strike missions steadily escalated, as punitive strikes against Iraqi installations were authorized in response to provocative acts such as Iraqis targeting and launching surface-to-air missiles at Coalition aircraft. The RO (response option) missions targeted command and control sites, Iraqi airfields, and Iraqi Republican Guard positions, in response to Iraqi intransigence.

The tempo of operations of OSW reached its peak in the final three weeks leading into OIF. In addition to striking ground targets in Southern Iraq, 'strike familiarization' missions were launched, where Hornets loaded with ordnance were sent over Iraq, but did not use their weapons. During these missions, vital information such as intelligence on surface-to-air missiles (SAMs) and anti-aircraft artillery (AAA) sites, familiarization with navigation waypoints and terrain landmarks were gathered, all carried out in preparation for OIF.

Reconnaissance imagery on targets was also crucial. In this role, US Marine Corps F/A-18Ds equipped with the Advanced Tactical Air Reconnaissance System (ATARS) pod continued their broad area surveillance and brought vital information crucial for the subsequent strike missions of OIF. The ATARS system was a removable pallet containing three primary sensors loaded in the weapons bay that normally housed the M61A1 Vulcan 20mm cannon.

The equipment included infrared, electrooptical and radar sensors. The ATARS equipped F/A-18D aircraft, based at Al Jaber Air Base in Kuwait, were often given freedom to fly virtually anywhere within the no-fly zone. In addition, ATARS equipped F/A-18Ds were allowed to overfly Basra and areas beyond the 33rd Parallel, in preparation for the impending air campaign of Operation Iraqi Freedom.

OPERATION IRAQI FREEDOM – THE HORNET'S WAR

On March 20, 2003, the first strike of Operation Iraqi Freedom, the effort to depose Saddam Hussein, was flown. During the evening, a precision air strike on a Republican Guard compound was executed by two Lockheed F-117A Nighthawks, after intelligence reported that Saddam Hussein and four of his top commanders had entered the location. While the intelligence proved incorrect, all the targets allocated were destroyed during the strike.

At this time, the US Navy had a total of five aircraft carriers assigned to OIF. The USS *Harry S. Truman* (CVN 75) and the USS *Theodore Roosevelt* (CVN 71) operated in the Mediterranean, while the USS *Constellation* (CV 64), USS *Kittyhawk* (CV 63), and USS *Abraham Lincoln* (CVN 72) were deployed to the Northern Arabian Gulf. The USS *Nimitz* (CVN 68) later replaced the USS *Lincoln*.

Over 250 Hornets were assigned to OIF, mostly with carrier-based US Navy and US Marine Corps strike fighter squadrons. The majority of these carrier-based Hornets were F/A-18C models, with the exception of US Navy Reserve Squadron VF-201 and the United States Marine Corps VMFA-115 Squadron which flew the F/A-18A+ version with upgraded radar and avionics.

In addition to carrier-based Hornets, the US Marine Corps F/A-18 Hornets from the 2nd and 3rd Marine Aircraft Wing were deployed to Al Jaber Air Base in Kuwait. Colonel Bob 'Brutus' Charette Jr., was the commanding officer of VMFA-323 between 2003 and 2005 and had flown F/A-18 Hornet missions during Operation Desert Shield and Operation Desert Storm.

Colonel Charette recalled his experience landing at Al Jaber Air Base: "Our F-18 Marine Air Squadron was based at Al Jaber Air Base. More than 10 years before, during Operation Desert Storm, I had bombed this same air base multiple times when it was occupied by Iraqi air forces.

"When our squadron returned to Al Jaber in 2003, the bomb damage we inflicted on the hardened aircraft shelters was still there. For me, the time I spent at Al Jaber during Operation Iraqi Freedom brought back memories of the missions I flew during Operation Desert Storm."

In addition to the US Navy and the US Marine Corps, the Royal Australian Air

Northern Iraq, April 11, 2003. An F/A-18 Hornet strike fighter assigned to Strike Fighter Squadron Three Seven (VFA-37) embarked aboard USS *Harry S. Truman* (CVN 75) resumes a combat mission in direct support of Operation Iraqi Freedom. Note the laser guided bombs loaded into the outer wing pylons and the Nite HAWK Forward Looking Infra-Red FLIR targeting pod positioned on the port fuselage pylon adjacent to the centreline drop tank. **US Navy**

US NAVY HORNET SQUADRONS INVOLVED IN OPERATION IRAQI FREEDOM

USS *Constellation*
VFA-151 'Vigilantes' (F/A-18C)
VFA-13 7 'Kestrels' (F/A-18C)
USS *Kitty Hawk*
VFA-27 'Royal Maces' (F/A-18C)
VFA-192 'World Famous Dragons' (F/A-18C)
VFA-195 'Dam busters' (F/A-18C)
USS *Nimitz*
VFA-41 'Black Aces' (F/A-18F)
VFA-14 'Tophatters' (F/A-18E)
VFA-97 'Warhawks' (F/A-18A)
VFA-94 'Mighty Shrikes' (F/A-18C)
USS *Abraham Lincoln*
VFA-115 'Eagles' (F/A-18E)
VFA-113 'Stingers' (F/A-18C)
VFA-25 'Fist of the Fleet' (F/A-18C)
USS *Harry S. Truman*
VFA-37 'Bulls' (F/A-18C)
VFA-105 'Gunslingers' (F/A-18C)
USS *Theodore Roosevelt*
VFA-201 'Hunters' (F/A-18A+)
VFA-15 'Valions' (F/A-18C)
VFA-87 'Golden Warriors' (F/A-18C)

Force (RAAF) sent 14 F/A-18As from 75 Squadron to Al Udeid Air Base in Qatar. These RAAF F/A-18As had the APG-73 radar, updated Identification-Friend-Foe (IFF) transponders, and AMRAAM capabilities equivalent to upgraded US F/A-18A+.

Initially the RAAF F/A-18s were tasked with direct counter air missions to protect reconnaissance RC-135 and E-8 JSTARS as well as the vital aerial tankers. later on, as the Iraqi air threat did not materialize, the RAAF F-18s were tasked with close air support and interdiction missions, using laser guided bombs.

Finally, in addition to original Hornets, VF-115 operated the F/A-18E Super Hornet, along with F/A-18F Super Hornets from VF-114 and VF-41.

A United States Air Force KC-10 Extender refuels a F/A-18C Hornet assigned to Strike Fighter Squadron One One Three (VFA-113) during a patrol over the no-fly zone in Southern Iraq. A typical F/A-18 Hornet mission in Operation Southern Watch included multiple air-to-air refuelling evolutions, including refuelling after launch from the aircraft carrier, waiting for the assigned time on station in the no-fly zone, and finally refuelling prior to recovery back to the aircraft carrier. **US Navy**

GUIDED MUNITIONS

For F/A-18 strike missions during OIF, the Joint Direct Attack Munition ODAM) was the key weapon employed. The main advantage of the JDAM was that it was released in level flight at high altitude, therefore protecting launching aircraft from the threat of SAMs and AAA.

Another major advantage was its complete autonomy after release, in comparison to laser-guided or electro-optical bombs which could be affected by poor weather or loss of target lock by the launch or designating aircraft. The components of the JDAM included a standard unguided bomb, such as a 1000lb (454kg), 2000lb (907kg) or BLU-109 penetrator unguided bomb, along with a GPS guidance control unit, ventral strakes, and a steerable tail control unit.

For bombing fixed targets, GPS coordinates were loaded by the Hornet pilot into his memory unit or mission data loader via the Tactical Aircrew Mission Planning System (TAMPS). During a mission, if a target of opportunity arose, the pilot entered the coordinates into the Hornet's mission computer.

The pilot used his radar and FLIR pod for reprogramming the JDAM in flight. In addition to JDAMs, the Joint-Stand Off Weapon OSOW) was also employed, mostly against pre-planned targets, including command and control centres, as well as Iraqi SAM sites. Other munitions used by Hornet crews included laser guided bombs, AGM-88 anti-radiation missiles against SAM and radar sites, as well as air-to-ground missiles such as the AGM-130 and AGM-84 SLAM-ER, which were effective for striking fixed pre-planned targets.

Colonel Charette summarized his first-hand experience with the evolution of precision guided munitions: "During Operation Desert Storm, we employed a lot of unguided munitions, ordinance left over from the Vietnam era. During Operation Allied Force in Bosnia, we started employing laser guided bombs. Finally during Operation Iraqi Freedom, all my strike missions involved GPS-guided precision guided munitions such as JDAMs."

SHOCK AND AWE

The entire OIF campaign was designed to start with a massive air strike 'A-Day', ➤

US MARINE CORPS HORNET SQUADRONS INVOLVED IN OPERATION SOUTHERN WATCH AND OPERATION IRAQI FREEDOM

VMFA-115 'Silver Eagles' (F/A-18A)
VMFA(AW)-121 'Green Knights' (F/A-18D)
VMFA(AW)-224 'Bengals' (F/A-18D)
VMFA(AW)-225 'Vikings' (F/A-18D)
VMFA-232 'Red Devils' (F/A-18C)
VMFA(AW)-242 'Bats' (F/A-18C)
VMFA(AW)-533 'Hawks' (F/A-18D)

A US Marine Corps F/A-18A+ Hornet assigned to the 'Silver Eagles' of Marine Fighter Attack Squadron One One Five (VMFA-115), receives fuel from a US Air Force KC-10 Extender assigned to the 908th Expeditionary Air Refuelling Squadron. **US Navy**

The Arabian Gulf. March 19, 2003 – aviation ordnancemen aboard USS Abraham Lincoln (CVN 72) load a Joint Direct Attack Munition (JDAM) on to a F/A-18C Hornet during Operation Southern Watch. **US Navy**

followed by a ground war. Following the initial precision strike executed by the F-117s, the first bombs of A-Day were designed to fall on target in Baghdad at 2100 hours local time, March 21, 2003.

The first strike from the US Navy Carrier Battle Group came in four waves – the initial strikes were from Tomahawk cruise missiles launched from naval assets off the Arabian Gulf, followed by F/A-18 Hornets employing the JSOW, strikes by stealth aircraft, then finally F/A-18Cs and F-14Ds loaded with JDAMs.

Captain Mark Fox, Commander Air Group, Carrier Air Wing-2, recounted the opening night of air strikes against Baghdad in the book US Navy Hornet Units of OIF. He flew an F/A-18C on the first night of carrier-based tactical air strikes against Baghdad: "Baghdad – a city the size of Detroit – was faintly invisible on the horizon in the east, to the naked eye, but brightly lit in green hues when viewed through night vision goggles. Familiar geography emerged. Looking east – the Tigris and Euphrates rivers were defined by the cultural lighting of Iraq's southern towns and cities, while the ink-black expanse of the desert to the west was marked only by an occasional light.

"Things were heating up on the north – our Prowlers started jamming, kicking off the most impressive fireworks display I've ever seen. Dozens of SAMs launched and began to arc gracefully upward, some exploding well above our altitude, others snuffing out in mid-flight. Baghdad's hundreds of AAA sites punctuated the night sky, their random streams of muzzle flashes sparkling like the widespread flash photography in a stadium at the end of the Superbowl."

Captain Fox commented on the Iraqi air defences: "The Iraq defences were spectacular but ineffective – none of the SAMs were guiding, no one had any indication of being illuminated by fire control or target tracker radars, and the vast majority of the fireworks were going off below us. An occasional nearby AAA burst or SAM explosion above us kept our eyes out of the cockpit and our jets in continuous manoeuvre however."

The 'shock and awe' phase of OIF not only included targets in Baghdad, but also several in Karbala and the AAA and SAM sites in Southern Iraq. Prime Iraqi Air Force targets hit during the opening air campaign included the H-1, H-2, and H-3 airfields in western Iraq. The first 72 hours of the opening air campaign of OIF were impressive; more targets were struck during this short time than in all of the pre-planned missions during the air campaign of Operation Desert Storm in 1991.

CLOSE AIR SUPPORT AND BATTLEFIELD INTERDICTION

In the subsequent weeks of March and April 2003, the ground phase of Operation Iraqi Freedom progressed as the US Army's V Corps and US Marine Corps' First Marine Expeditionary Force sped towards Baghdad from Kuwait An increasing shift in priorities meant that more close air support and battlefield air interdiction missions were executed by F/A-18 Hornet crews and other tactical air assets.

Central command allowed ground commanders to divide their areas into a grid of 18.5 mile by 18.5 mile, so-called 'kill boxes' which were declared either closed or open depending on whether friendly troops were present in the area.

US Marine Corps Forward Air Control (FAC-A) crews on board F/A-18Ds often coordinated the prosecution of these kill boxes. Their complex task included identifying targets, coordinating with ground forward air controllers, as well as orchestrating strikes from multiple sections of tactical aircraft stacked at altitudes from 15,000 to 31,000ft (4572-9449m).

The F/A-18 units from the three aircraft carriers in the Northern Arabian Gulf were tasked with strike missions on preplanned targets and close air support missions supporting the large mechanized infantry formations involved in the advance on Baghdad. In contrast, the USS *Harry S. Truman* and the USS *Theodore Roosevelt* in the Mediterranean were tasked with supporting smaller ground units consisting of Special Operations Forces in the northern part of Iraq, working in coordination with Kurdish fighters.

A typical Forward Air Control team in Northern Iraq consisted of two Special Operations Force operatives equipped with a Viper laser designator to pinpoint targets, teamed up with local Kurdish Peshmerga

Mediterranean Sea, March 21, 2003 – 2000lb (907kg) Joint Direct Attack Munitions (JDAMs) are loaded on to one of four aircraft elevators for transport to the ship's flight deck aboard USS *Harry S. Truman* (CVN 75). JDAMs are guidance kits that convert existing unguided bombs into precision-guided 'smart' munitions. The tail section contains an inertial navigational system (INS) and a global positioning system (GPS). The JDAM was one of the most commonly deployed precision guided munitions during F/A-18 Hornet missions of Operation Iraqi Freedom. **US Navy**

militia. Vital bridges, SAM sites and tank and infantry formations were targeted in Northern Iraq, preventing them from coming south to assist with the defence of Baghdad.

As Coalition ground forces pushed further north into Iraq, plans were implemented to increase the modest loiter time of the F/A-18 Hornet as they were operating at longer ranges from their aircraft carriers. The modest range of the Hornet was further complicated by the relative scarcity of tanker support, a factor that plagued the air campaign of OIF.

Initially, Hornets switched from carrying two to three external tanks, with the additional tank giving an additional 30 to 40 minutes on station. A further solution was provided by the Super Hornets from VF-115, which were configured to provide air-to-air refuelling for Carrier Air Wing-14.

During missions to Baghdad, a two-ship section of F/A-18C and D Hornets was accompanied north by a single F/A-18E Super Hornet tanker, which carried four external fuel tanks and a buddy refuelling store. By refuelling at higher altitudes with the Super Hornet, the older versions of the Hornet saved valuable time and fuel normally required to descend to a lower altitude and to locate a US Air Force tanker.

Mediterranean Sea, March 20, 2003 – an F/A-18 Hornet pilot performs a routine maintenance check prior to launching from one of four steam powered catapults on the flight deck of the USS *Harry S. Truman* (CVN 75). **US Navy**

As the list of targets and air threats dwindled with the progress of the campaign, Coalition aircraft faced an increased threat from Blue on Blue accidents. On the night of April 2, 2003, Lieutenant Nathan White of VFA-195 launched from CV-63, to support elements of the 3rd Infantry Division that were taking heavy fire in Karbala, 50 miles south of Baghdad. During the return flight to the USS *Kitty Hawk*, Lt White's F/A-18C was engaged and destroyed by a US Army PAC-3 Patriot missile battery.

The F/A-18C crashed into a lake in an Iraqi Air Force bombing range near Karbala. The conclusion of the formal investigation revealed that the operators of two Patriot missile batteries mistakenly identified F/A-18C as an incoming Iraqi missile. Prior to this incident, a Patriot Missile battery had also engaged and destroyed a Royal Air Force Tornado GR.4. Lt White's remains were recovered on April 12, and he was buried with full military honours at Arlington National Cemetery 12 days later.

COMBAT-PROVEN STRIKE FIGHTER

Both Operation Southern Watch and Operation Iraqi Freedom demonstrated the versatility of the F/A-18 Hornet and reaffirmed the concept of the strike fighter. Throughout the air campaign, Hornet crews demonstrated the aircraft's multirole capability as it performed multiple and frequently changing missions that were re-tasked once airborne. These included operations in the direct counter air, combat air patrol, close air support, forward air control, battlefield interdiction, air tanker, and reconnaissance roles.

Secondly, both operations highlighted the importance of precision guided

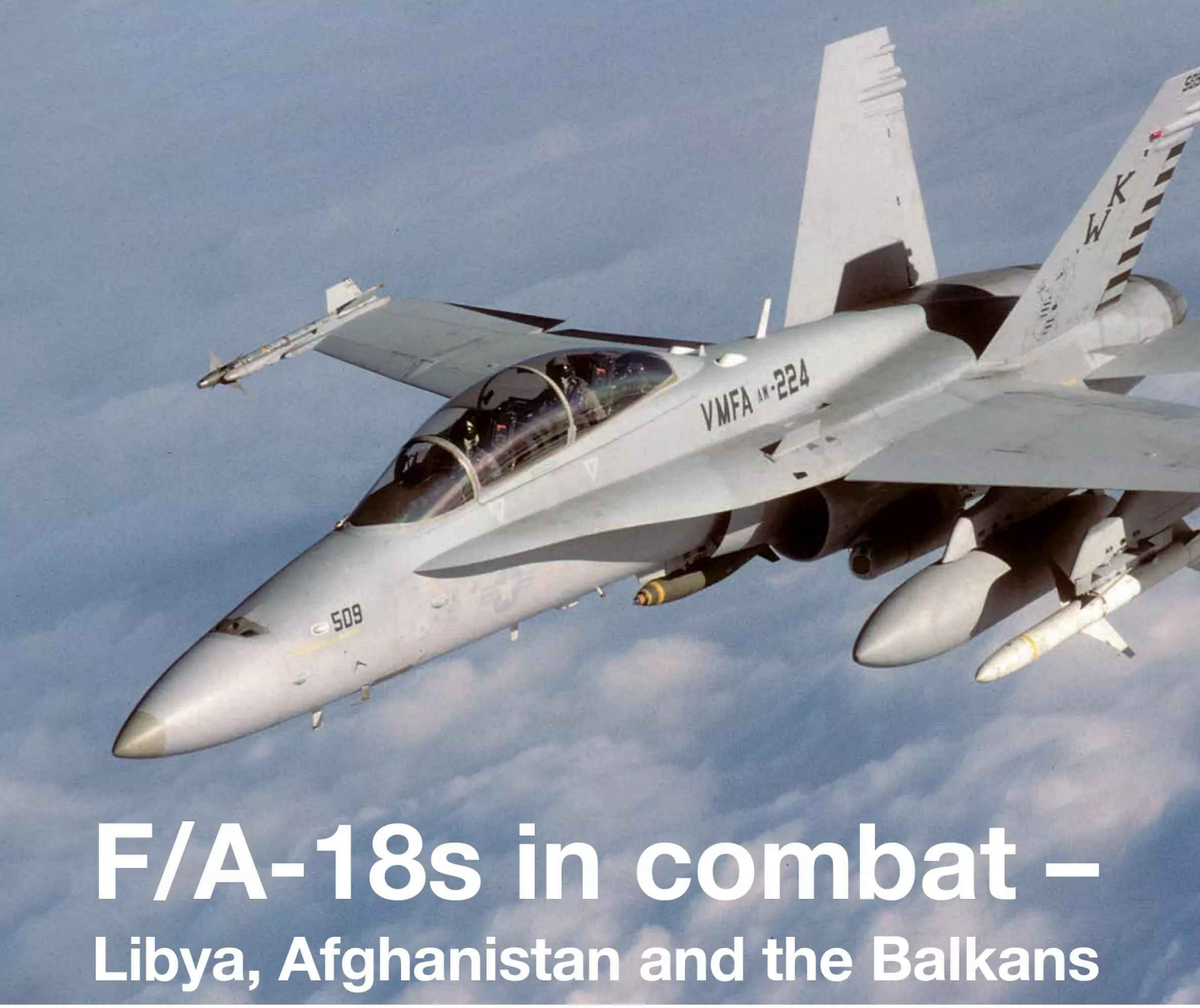
A US Marine Corps F/A-18 Hornet loaded with the ATARS reconnaissance pallet. ATARS equipped US Marine Corps F/A-18Ds provided vital intelligence for combat missions during Operation Iraqi Freedom. **US Marine Corps**

munitions such as JDAM, JSOW, and laser guided bombs to the strike capability of the modern carrier battle group.

Finally, Operation Iraqi Freedom illustrated the importance of close coordination between air assets and ground forces as F/A-18 Hornet aircrews coordinated with forward air controllers, both in the air and on the ground, to decimate enemy forces and shape the battlefield.

Rear Admiral Jim Maslowski, who flew A-4 Skyhawks during the Vietnam War, was the commanding officer of the USS *Kittyhawk* during Operation Southern Watch. He summarized the revolution in carrier strike operations exemplified by the F/A-18 Hornet: "When I flew the A-4 in Vietnam, we carried unguided bombs and relied on fixed sights for dive bombing in strike missions. Several decades later, we have high performance aircraft such as the F/A-18, with the increased range, multirole capability, precision guided munitions, and an improved capability to carry unused ordinance back to the aircraft carrier. Such aircraft, along with all the other developments of the carrier battle group, have revolutionized strike warfare."

■ Words: *Emmanuel Rodriguez*



F/A-18s in combat – Libya, Afghanistan and the Balkans

Operations Prairie Fire, El Dorado Canyon, Deny Flight, Deliberate Force, Allied Force, Enduring Freedom and Unified Protector

The F/A-18 Hornets of the US, Canada and Spain have been involved in a number of conflicts in the Mediterranean and Balkan region, from the first patrols over the Gulf of Sidra in 1986 to the intervention in the Libyan Civil War in 2011. The US Hornets have also been active for many years in combating insurgents in Afghanistan.

The first combat operations by the F/A-18 Hornet were carried out over the Gulf of Sidra off the north coast of Libya in response to Libyan support for terrorist organisations and the establishment by Colonel Muammar Gaddafi of a 'Line of Death' across the Gulf of Sidra in 1973. This line ran from Benghazi to Tripoli and was a restriction of international waters, closing off a large section of the Mediterranean to any military or merchant shipping.

Between 1981 and 1985, aggressive manoeuvres by elements of the Libyan Air Force had led to open conflict between Libyan and US Forces. The attack on the Italian cruise liner Achille Lauro in September 1985 by Libyan sponsored Palestinian terrorists, followed by the machine gunning of passengers at the airports of Rome and Vienna in December that year brought tensions in the region to a new peak.

OPERATION PRAIRIE FIRE

In response to these attacks, Operation Attain Document was planned to exercise freedom of navigation rights in the international waters of the Gulf of Sidra. This was expanded to include air operations under the title of Operation Prairie Fire.

Essentially, the US Navy was going

An F/A-18D of VMFA(AW)-224 with a mixed load of unguided bombs, an AGM-88 HARM anti-radiation missile and a pair of AIM-9 Sidewinder air-to-air missiles for self-defence. The two-seat all-weather Hornets were an invaluable asset during the many operations over the former Yugoslavia. **Luigino Caliaro**

The USS *Coral Sea* (CV 43) went to the Mediterranean for Operation Prairie Fire with two US Navy and two US Marine Corps Squadrons of brand-new F/A-18A Hornets aboard. Here one of the Hornets is launched from the starboard bow catapult while another waits to launch from the port. **US Navy**

Left: A Libyan Nanuchka class corvette burning in the Gulf of Sidra, March 24, 1986. **US Navy**

Below: An F/A-18A Hornet of VFA-132 lands back aboard the USS *Coral Sea* in 1986. **US Navy**

to trail its coat in the face of the Libyan forces, the mission being twofold; firstly, it was expected that the Libyan Air Force and Navy would react strongly to such provocation, and secondly, the Libyan air defence system had recently been upgraded with Soviet made SA-5 (S-200) Gammon surface-to-air missiles and their attendant Square Pair (5N62) fire control radars. Little was known about this long-range defensive system, and it was hoped that electronic and performance intelligence would be acquired.

The USS *Saratoga* (CV-60) was already in the area and had conducted operations against the Achille Lauro hijackers with its F-14 Tomcats and other aircraft. Joining the Saratoga was the USS *Coral Sea* (CV-43), which had sailed on its six-month cruise on October 1, 1985. The Coral Sea was an older, smaller carrier, which could not operate the F-14. Instead, aboard the ship was Carrier Air Wing 13 (CVW-13), equipped with four Squadrons of F/A-18A Hornets. ➤

An F/A-18 Hornet of Marine Fighter Attack Squadron (VMFA) 314 fires an AIM-9 Sidewinder missile, circa 1984. VMFA 314 and 323 were the first two US Marine Corps F/A-18 squadrons, and were both aboard the USS *Coral Sea* during Operation Prairie Fire. **National Museum of Naval Aviation**

These were VFA-131, the Wildcats and VFA-132, the Privateers, the first operational US Navy Hornet units, as well as VMFA-314, the Black Knights and VMFA-323, the Death Rattlers, the first operational US Marine Corps Hornet units. The two carriers began conducting operations off the Libyan coast, south of the 'Line of Death' in January and February 1986, during which time 130 interceptions of Libyan fighter aircraft had been made but no combat had been initiated, any threat to the carriers was intercepted and escorted away by F-14s and F/A-18s.

The Libyan aircraft encountered included Mikoyan Gurevich MiG-23s and MiG-25s and Dassault Mirage 5Ds and F.1s. In March, a third carrier, the USS *America* (CV-66) joined the Mediterranean force, along with several other ships including the battleship USS *Iowa* (BB-62), bringing the total US naval force in the region to 30 ships. On March 23, operations of the expanded force began inside the Gulf of Sidra. The following day, from midday, the Libyan Air Force sent MiG-25s to intercept US F-14s and launched some SA-5 missiles against them, but failed to shoot any down.

The F-14 and F/A-18 units supported Grumman A-6E Intruder and Vought A-7E Corsair II strikes against Libyan patrol ships and fast missile boats heading towards the US fleet and SA-5 missile sites near Syrte beginning at 7pm, followed by an attack on a Libyan corvette and missile boat around 10pm.

Further SA-2 and SA-5 missile launches near midnight from sites near Syrte and Benghazi were met with AGM-88 HARM missiles from A-7Es which disabled the site's radars. Finally, in the early morning of March 26, a second Libyan corvette was engaged and sunk by A-6Es, this and the attacks on the ships earlier being the first use of the AGM-84 Harpoon anti-ship missile.

At 08.30, Operation Prairie Fire was officially terminated, the Libyans having lost two Combatante II fast missile boats and a Nanuchka class corvette along with several missile system radars. The F/A-18 had had its baptism of fire, albeit in a fighter support role to the strike aircraft.

OPERATION EL DORADO CANYON

Libya responded to the military actions of March 1986 with terrorist attack on a discothèque frequented by US military personnel in Berlin on April 5, killing three people and injuring 229 more. In response to this, a US Air Force strike against Libya was discussed by the US with NATO and Arab partner nations, an idea that had been tested in Operation Ghost Rider on October 18, 1985.

Ghost Rider was an exercise by 10 General Dynamics F-111Es of the 20th Fighter Wing (TFW) based at Upper Heyford in the UK, which saw the aircraft attack a simulated airfield in Newfoundland and return to the UK with the assistance of air-to-air refuelling assets.

The success of this exercise meant that Operation El Dorado Canyon was planned to attack targets around Tripoli, including the airfield and barracks with 18 F-111Fs from the 48th TFW also from Upper Heyford, supported by four EF-111 electronic warfare aircraft.

On April 14, 1986, between 17.45 and 19.34 hours GMT, the strike force left the UK with 46 tankers and seven spare F-111s. At 22.20, the US Navy carriers still in the Gulf of Sidra launched F-14s and other support and surveillance aircraft to support the strike.

Shortly after this, the USS *Coral Sea* launched 18 F/A-18As from the four squadrons, split between fighters and attack aircraft armed with AGM-88 HARM and AGM-45 Shrike antiradiation missiles.

These accompanied eight A-6Es and an EA-6B electronic warfare aircraft. While the F-111 force struck their targets around Tripoli, the US Navy aircraft struck Benina airfield and targets around Benghazi to split the Libyan defences. Six of the F/A-18s armed with four Shrikes and 20 HARMs fired all of their missiles at the air defence network radars around Benghazi, clearing the way for A-6E force.

As all of the aircraft withdrew, a single F-111F was shot down over the Gulf of Sidra some 30km off the coast of Libya. The Libyans fired two Scud missiles aimed at a US Coastguard station on the Italian Island of Lampedusa by way of retaliation, but these missed. The F-14s were to be involved in one more combat over the Gulf of Sidra with Libyan MiG-23s on January 4, 1989, but this was to be the last US air action over Libya until 2011.

OPERATION DENY FLIGHT

The breakup of the former Yugoslavia in 1991 was to result in a number of internecine conflicts between the nation states that formed after the dissolution of the country. The first conflict began between Serbia and Croatia on March 31, 1991, where Serbian nationals inside Croatia attempted to take control of Croatian territory where they formed a majority.

A ceasefire in January 1992 after the Republic of Croatia was recognised as a sovereign state led to the war becoming sporadic until 1995, when Croatia launched two offensives that ended the conflict on November 12. This situation was further complicated by the war inside the Republic of Bosnia and Herzegovina, fought between the forces of that country and those of the Bosnian Serb Republika Srpska supplied by Serbia and Herzeg-Bosnia supplied by Croatia.

The resulting war between the factions began on March 1, 1992, and was bitter in

VMFA(AW)-332 took part in Operation Deny Flight from October 1994 until March 1995 with their F/A-18Ds. They returned to the area in May 1999 to Taszar AB in Hungary to participate in Operation Allied Force and Operation Joint Guardian. **USMC via Warren Thompson**

US NAVY AND US MARINE CORPS UNITS THAT TOOK PART IN OPERATION DENY FLIGHT, DELIBERATE FORCE AND ALLIED FORCE

Unit and aircraft	Deployment years
VFA-15 – F/A-18C	1999
VFA-37 – F/A-18A	1992, 1993, 1994, 1996 and 1999
VFA-82 – F/A-18A	1992
VFA-83 – F/A-18A	1992
VFA-86 - F/A-18A	1993 and 1994
VFA-87 – F/A-18C	1993, 1995, 1997 and 1999
VFA-131 – F/A-18C	1994 and 1996
VFA-136 – F/A-18A	1994 and 2000
VMFA-251 – F/A-18A	1994 (Aviano, Italy)
VMFA-312 – F/A-18A	1993 and twice more in 1995
VMFA(AW)-224 – F/A-18D	1994 and 1995 (Aviano, Italy)
VMFA(AW)-332 – F/A-18D	1994, 1995, 1996 (Aviano, Italy) and 1999 (Taszar, Hungary)
VMFA(AW)-533 – F/A-18D	1993 and three more deployments up to 1998 (Aviano, Italy) then 1999 (Taszar, Hungary)

An F/A-18 Hornet of CVW-1 is launched from the waist catapult of the USS *Theodore Roosevelt* while an aircraft of VMFA-251 is parked on the bow of the ship during flight operations in support of Operation Enduring Freedom on December 31, 2001. **US Navy**

Two of the CF-18s deployed to Aviano Air Base in Italy depart for home after taking part in Operation Allied Force and Operation Echo on December 21, 2000. **USAF**

the extreme, featuring massacres, rapes and ethnic cleansing on a horrifying scale; a conflict that would not end until December 14, 1995.

The use of air power in the conflicts by Bosnian Serbs, and incursions into Bosnian airspace from Croatia and Serbia led to concerns being raised in the UN about the safety of the civilian population. Resolution 781 was passed which prohibited unauthorised flights over Bosnia and a NATO monitoring force being set up in October 1992 under the title of Operation Sky Monitor. By April 1993, over 500 violations had been recorded, so UN Resolution 816 was passed which allowed NATO to enforce the no-fly zone, and Operation Deny Flight was begun on April 12.

Armed patrols by a variety of NATO aircraft saw an immediate effect, cutting the unauthorised fixed wing flights over the area to one seventh of their pre-operation level. Helicopters were another matter. Fake markings were applied to the helicopters of the belligerents which made identification difficult and the restrictive rules of engagement meant that nearly 6000 unauthorised helicopter flights were made during the operation.

As well as enforcing the no-fly zone, the aircraft of Deny Flight were also supporting Operation Sharp Guard, the NATO naval blockade of the region to prevent arms shipments from reaching the combatants. The troops of the United Nation Protection Forces (UNPROFOR) operating in Bosnia were increasingly under attack from all sides, so on June 10, 1993, UN Resolution 836 was passed which allowed the NATO aircraft of Deny Flight to fly close support missions for UNPROFOR.

Between this time and the end of Operation Deny Flight on December 20, 1995, 23,021 fighter sorties and 27,077 close air support sorties were flown over Bosnia-Herzegovina supported by 21,164 Airborne Early Warning, tanker, supply, Suppression of Enemy Air Defence (SEAD) and reconnaissance missions. These were flown by 239 aircraft from eight nations, 108 of which were from the United States, the US Navy F/A-18 units being based on aircraft carriers, while the US Marine Corps flew from Aviano Air Force Base in Italy. The Marine Corps Hornets included the two seat F/A-18Ds developed as all-weather and night attack aircraft, which proved both accurate and reliable in their many missions. ➤

An F/A-18C from the 'Mighty Shrikes' of Strike Fighter Squadron Nine Four (VFA-94) based on the USS *Carl Vinson* carries a JDAM (Joint Direct Attack Munition) on a mission in support of Operation Enduring Freedom on November 4, 2001. **US Navy**

These US Hornets were joined on November 18, 1994, by a detachment of eight Spanish Air Force EF-18s, which were to also operate from Aviano. The Spanish detachment also included two of their KC-130H tanker aircraft, a welcome addition to the tanker force.

The range of tasks carried out by the F/A-18s exercised all of the capabilities of the aircraft, from close air support and striking at enemy forces, air defences, fuel and ammunition dumps, to acting as forward air controllers and flying reconnaissance missions.

At the end of Deny Flight, the aircraft taking part were retasked to Operation Decisive Endeavour, providing air support to the NATO Implementation Force (IFOR) as UNPROFOR had become as well as the UNRNCRO force operating in Croatia. Between August and November 1997, Royal Canadian Air Force CF-18s were sent to Aviano air base in Italy to support NATO peacekeeping forces in Croatia and Bosnia and Herzegovina by flying armed deterrent patrols.

The continuing violence in the former Yugoslavia meant that 18 CF-18s were to return to Aviano in June 1998 and were to remain deployed until December 21, 2000, flying combat air patrols over Bosnia and Herzegovina and Kosovo during that time. The overall NATO Operation in the region was renamed Joint Endeavour, aimed at implementing the peace agreements of the Dayton Accords and maintaining the hard-won ceasefires.

OPERATION DELIBERATE FORCE

During Operation Deny Flight, between August 30 and September 20, 1995, a concerted air campaign was launched by NATO against the Army of the Republika Srpska, a Bosnian Serb organisation seeking control of the Bosnian territories where Serbians made up the majority.

Funded and supplied by Serbia, these irregular units had a vast array of modern heavy weapons including armour and artillery. During the latter half of 1994 and early 1995, the activities of this army had grown more aggressive. Attacks on civilian populations, NATO designated safe areas and NATO forces themselves culminated in July 1995 with the massacre of over 8000 Bosnians at Srebrenica, a UN safe area for the local Bosnian Muslim population.

On August 28, this atrocity was followed by the Markale massacre in Sarajevo. With forces moving on other safe areas, NATO responded with Operation Deliberate Force. More than 400 NATO aircraft, including the US and Spanish F/A-18s, flew 3515 sorties against 338 Bosnian Serb military targets while reconnaissance missions provided target information for NATO artillery units and sea launched Tomahawk cruise missiles. Targets included ammunition and other supply dumps, as well as military forces and convoys.

The F/A-18s, F-15Es and Tomahawk cruise missiles also struck communications and radar installations, especially the radio relay stations required for rebroadcast radio signals in the mountainous areas of the county. The NATO air strikes coincided with operations by the Croat and Bosnian armed forces that recaptured a great deal of the territory taken by the Bosnian Serbs and forced them onto the defensive.

The air strikes were stopped on September 15, after an agreement was reached with the Bosnian Serbs to withdraw all heavy weapons from the area around Sarajevo and to cease their bombardment of civilian populations. Operation Deliberate Force played a significant part in forcing the Serbs to the negotiating table, talks which resulted in the Dayton Peace Agreement in November 1995.

UNPROFOR became IFOR, to implement these agreements, until December 1996, when the IFOR mission was completed and the NATO forces in

The nuclear-powered aircraft carrier USS *George Washington* (CVN 73) and guided missile destroyer USS *Arthur W. Radford* (DDG 968) conduct replenishment at sea operations in the western Mediterranean on July 11, 1996. George Washington's battle group was operating in support of the NATO-led peace keeping efforts in Bosnia under Operation Decisive Endeavor in the Adriatic as well as the UN sponsored sanctions against Iraq, under Operation Southern Watch in the Arabian Gulf. **US Navy**

country became the Stabilisation Force (SFOR). This force too was replaced, in December 2004, by EUFOR Althea, a European Union Force which currently stands at around 900 deployed troops from 26 nations.

OPERATION ALLIED FORCE

In 1992, Serbia and Montenegro had jointly formed the Socialist Federal Republic of Yugoslavia, and began the supporting military actions in Croatia and Bosnia, essentially in order to force the recreation of a Serb-led Yugoslavia.

With the failure of this ambition and the end of the Bosnian War in 1995, Montenegro began to separate itself from some of the more extreme policies of the Serbian Government, so by 1996 the two countries were wholly separated in terms of administration and finance, the remaining agreements between the two only affecting such elements as defence.

The southern region of Serbia, a province called Kosovo, bordered both Montenegro and Albania to the south. The population of the region was predominantly ethnic Albanians who since the 1980s had become increasingly vociferous in their demands for autonomy and for the few Serbs in the region to leave. In the early 1990s, Serbia had seen fit to repress the Kosovar Albanian population with closures of the Albanian language press and restrictions in their television and radio programming.

Kosovar Albanians employed in public service positions were fired and the university departments staffed by them were closed. In 1991 with the dissolution of Yugoslavia, the Kosovo Liberation Army (KLA) was founded, initially acting against Serbian law enforcement during 1995 and 1996. In 1997, the collapse of the Albanian economy and the armed rebellion in the country saw many police and army barracks looted for weapons. A great many of these were smuggled to the KLA which increased the scale of its operations against the Yugoslav forces in Kosovo, beginning in February 1998.

Serbia responded by increasing the number of military and paramilitary units and targeted the KLA and its supporters, who at this time were listed as a terrorist organisation by the US. The KLA began a series of advances from the border with Albania, capturing a number of villages and towns as well as infiltrating areas of the region's capital Pristina.

By September, its units were operating in the northern sections of Kosovo. The Serbian forces responded strongly, and as in Bosnia the killing, raping and displacement of the civilian population became widespread, with more than a million people forced from their homes.

Artillery, armoured forces and aircraft were used to attack the KLA and centres of population, the aim being to drive the ethnic Albanians out of the region. The international community became increasingly concerned at the reports coming out of Kosovo and a ceasefire was agreed with NATO on October 15.

Ordnancemen inspect AGM-65 Maverick air-to-surface tactical missiles on the flight deck of USS *Enterprise* (CVN 65) during support of Operation Enduring Freedom. **US Navy**

Sadly, the fighting began again in December and a number of massacres of Kosovar Albanians occurred. In February 1999, NATO attempted to broker a peace treaty by hosting the Rambouillet Conference near Paris, but the establishment of a ground force similar to the SFOR operating in Bosnia was rejected by the Serbs. On March 23 the talks had failed so NATO's bombing campaign, Operation Allied Force, began the following day.

The aim was to force Serbia to withdraw its forces from Kosovo, allow a peacekeeping force and be established and the refugees to return to their homes. More than 1000 NATO aircraft based on aircraft carriers in the Adriatic and airfields in Italy, Germany and Hungary were to take part in the bombing, which also saw the use of cruise missiles against heavily defended targets.

Military targets both strategic and mobile were struck throughout Serbia and Kosovo. The first aircraft to bomb Belgrade on March 24 were Spanish Air Force EF-18 Hornets, eight of which were based at Aviano. These also flew SEAD missions that evening. Single seat US Navy Hornets operating from carriers in the Adriatic were joined by two seat F/A-18D all-weather attack aircraft of the US Marine Corps from Aviano and Taszar in Hungary.

The Royal Canadian Air Force, which as already mentioned had deployed 18 CF-18s to Aviano in 1998, flew 684 sorties using both guided and unguided bombs. This made up a remarkable 10% of all NATO bombing missions flown despite the aircraft making up just under 2% of the Allied air power committed to the region.

The CF-18 crews were drawn from 441 and 425 Squadrons, the Canadian part of Allied Force being known as Operation Echo. On June 10 the bombing was suspended after the Serbian Government accepted the terms of a NATO ground force in Kosovo, this becoming known as KFOR. The first units entered the region on June 12 under the NATO title of Operation Joint Guardian, establishing a number of operating bases, several of which are still in use today as the status of Kosovo remains unresolved. Kosovo declared independence from Serbia on February 17, 2008, and has been recognised by 108 UN member states, but NATO forces remain in the country as Serbia maintains its claim on the territory.

Just some of the ammunition expended by Carrier Air Wing 8 aboard the USS *Theodore Roosevelt* (CVN 71) on May 18, 1999, during Operation Allied Force over Kosovo. **US Navy**

OPERATION ENDURING FREEDOM

In 1996, the Afghan Civil War was being fought between the Taliban and the Northern Alliance. The Taliban were an Islamic political organisation who were operating with the assistance of the terrorist group Al Qaeda, Pakistan, which supplied men and arms, and Saudi Arabia, which supplied funding.

Fighting them were the combined forces of the United Front, sometimes called the Northern Alliance as they were made up of many ethnicities from the northern regions of Afghanistan. Osama bin Laden, the leader of Al Qaeda, had originally set up the organisation to help fight the Russian invasion of Afghanistan in the early 1980s, and was now using the country to set up training camps, build weapons caches and recruit followers, supplying many men, predominantly Arab and Pakistani, to the Taliban.

The Northern Alliance was being driven back by these combined forces, occupying just the northwest corner of the country, when the Al Qaeda attack on the World Trade Centre in New York on September 11, 2001, brought the conflict in Afghanistan onto the world stage. ➤

An F/A-18C Hornet carrying three LGBs prepares to take on fuel from a US Air Force KC-10 Extender while flying in support of Operation Enduring Freedom. Aircraft from the carriers USS *Carl Vinson* (CVN 70), USS *Theodore Roosevelt* (CVN 71), and USS *Kitty Hawk* (CV 63) were conducting round the clock bombing missions over Afghanistan at this point. **USAF**

The US demanded that the Taliban expel Al Qaeda and hand over the leaders responsible for the airliner attack on the twin towers. The Taliban, who knew nothing of the Al Qaeda operation, tried to reach an agreement where Osama bin Laden could be tried independently, but were unsuccessful.

On October 7, 2001, Operation Enduring Freedom was launched by the US and the UK, Special Forces troops from both countries joining the Northern Alliance and massive airstrikes being conducted, many by F/A-18 Hornets from US aircraft carriers in the Indian Ocean and Persian Gulf. Command, control and communication (C3) targets in the cities of Kabul, Kandahar and Jalalabad and the Taliban and Al Qaeda training camps were all struck in the first two weeks, before the air operations moved to attacking Taliban units on the front line.

US Navy and Marine Corps F/A-18s were heavily involved in these missions, using guided munitions against Taliban troops and vehicles. Daily close air support and interdiction missions became the norm as the Allied forces, now joined by units from Australia, Canada and New Zealand began to advance, taking the capital, Kabul, on November 13.

The Taliban collapsed at this point and by the end of November the last strongholds of the cities of Kunduz, Kandahar and the cave complexes in the Tora Bora Mountains were under siege and being heavily attack by allied air forces. Kunduz surrendered on November 26, Kandahar fell on December 7 and the final cave complex in the Tora Bora Mountains was cleared on December 17, the Al Qaeda and Taliban leadership escaping into Pakistan.

Prior to these final events of the ground war, the UN had passed Resolution 1378 condemning the Taliban for its support of Al Qaeda on November 14. This was followed on December 20, 2001, by the establishment of the UN International Security Assistance Force (ISAF), a force intended to secure Kabul initially, but eventually was to be responsible for the entire south-eastern half of the country until today.

Insurgency and attacks by Taliban and Al Qaeda forces from Pakistan into Afghanistan have continued from that time until today. The US Navy and Marine Corps Hornet units were operating in two theatres simultaneously throughout this campaign, the carrier forces in the Persian Gulf were flying strike and support sorties over Afghanistan as well as over Iraq as part of Operation Southern Watch and later Iraqi Freedom.

The F/A-18s remain in the region to this day as carriers rotate in and out of the Gulf, and even though the international military forces are intended to leave during 2014, given the US-Afghanistan Strategic Partnership Agreement of 2012, it is likely that US forces and aircraft will be operating in the region for at least another 10 years.

OPERATION UNIFIED PROTECTOR

The Libyan Civil War began on February 15, 2011, with a popular uprising aiming to overthrow the regime of Colonel Muammar Gaddafi. The indiscriminate use of the Libyan armed forces against the rebels and the civilian population led to UN Resolution 1973 on March 17, 2011, which authorised the establishment of a no-fly zone over Libya and action to be taken to protect civilians from attack.

On March 19, the British and US navies fired over 100 Tomahawk cruise missiles to eliminate the majority of the Libyan air defence system and other strategic targets before manned aircraft were committed. From that point on, strike aircraft were used to enforce the no-fly zone and to target Libyan forces where they threatened civilians and a naval blockade was in place to ensure no further arms shipments reached Libya.

Eventually, 19 nations were to provide forces or facilities in support of the operations. While the US forces deployed did not include any Hornets, both Canada and Spain were to despatch aircraft from their air

On board the USS *Theodore Roosevelt* (CVN 71) on October 27, 2001, an F/A-18 Hornet from the 'Sidewinders' of Strike Fighter Squadron Eight Six (VFA-86) prepares for launch. VFA-86 was part of Carrier Air Wing One (CVW 1) conducting missions in support of operation Enduring Freedom. **US Navy**

US NAVY AND US MARINE CORPS F/A-18 UNITS THAT TOOK PART IN OPERATION ENDURING FREEDOM

Unit and aircraft	Deployment years	Base	Notes
VFA-94 – F/A-18C	2001-2002	USS *Carl Vinson*	Made the first F/A-18 strike missions over Afghanistan
VFA-97 – F/A-18A	2001-2002	USS *Carl Vinson*	Strike missions over Afghanistan
VFA-87 – F/A-18C	2001	USS *Enterprise*	Operating as part of Southern Watch, then strike missions over Afghanistan
VFA-22 – F/A-18C	2001	USS *Carl Vinson*	Air combat patrols over Pakistan followed by missions over Afghanistan
VFA-82 – F/A-18C	2001	USS *John F. Kennedy*	Strike missions over Afghanistan
VFA-15 – F/A-18C	2001-2002	USS *Theodore Roosevelt*	Air combat patrols over Pakistan followed by missions over Afghanistan
VFA-86 – F/A-18C	2001-2002	USS *Theodore Roosevelt*	Strike missions over Afghanistan
VFA-27 – F/A-18C	2001	USS *Kittyhawk*	Strike missions over Afghanistan in support of Special Forces
VFA-192 – F/A-18C	2001	USS *Kittyhawk*	Strike missions over Afghanistan in support of Special Forces
VFA-195 – F/A-18C	2001	USS *Kittyhawk*	Strike missions over Afghanistan in support of Special Forces
VFA-146 – F/A-18C	2001-2002	USS *John C. Stennis*	Strike missions over Afghanistan
VFA-146 – F/A-18C	2001-2002	USS *John C. Stennis*	Strike missions over Afghanistan
VMFA-314 – F/A-18C	2001-2002	USS *John C. Stennis*	Strike missions over Afghanistan
VMFA-212 – F/A-18C (with F/A-18Ds of VMFA(AW)-332 in the FAC and reconnaissance role)			
	2002	Al Jabber Air Base Kuwait	Strike missions over Afghanistan and Iraq on Southern Watch
VFA-131 – F/A-18C	2002	USS *George Washington*	Strike missions over Afghanistan
VMFA(AW)-121 – F/A-18D	2002	Kyrgyzstan	Strike missions over Afghanistan
VFA-25 – F/A-18C	2002	USS *Abraham Lincoln*	Missions over Afghanistan and Iraq on Southern Watch
VFA-131 – F/A-18C	2004	USS *George Washington*	Strike missions over Afghanistan
VMFA-232 – F/A-18C	2005	USS *Nimitz*	Strike missions over Afghanistan and over Iraq as part of Iraqi Freedom
VFA-15 – F/A-18C	2005-2006	USS *Theodore Roosevelt*	Close air support operations over Afghanistan
VFA-86 – F/A-18C	2006	USS *Enterprise*	Strike missions over Afghanistan and over Iraq as part of Iraqi Freedom
VFA-131 – F/A-18C	2006-2007	USS *Dwight D. Eisenhower*	Strike missions over Afghanistan
VMFA-251 – F/A-18C	2007	USS *Enterprise*	Strike missions over Afghanistan and over Iraq as part of Iraqi Freedom
VFA-15 – F/A-18C	2008-2009	USS *Theodore Roosevelt*	Close air support operations over Afghanistan
VFA-87 – F/A-18A+	2008-2009	USS *Theodore Roosevelt*	Close air support operations over Afghanistan
VMFA-232 – F/A-18C/D	2010	Kandahar Air Base	Strike missions over Afghanistan
VFA-151 – F/A-18C	2010-2011	USS *Abraham Lincoln*	Missions over Afghanistan and in support of Operation New Dawn
VFA-87 – F/A-18A+	2011	USS *George H. W. Bush*	Support missions during Operation New Dawn and close air support operations over Afghanistan
VFA-151 – F/A-18C	2011-2012	USS *Abraham Lincoln*	Missions over Afghanistan

forces to take part in the operation. The Royal Canadian Air Force deployed seven CF-18s to the Italian Air Force Base at Trapani in Sicily. Known as Operation Mobile, these aircraft and crews flew air defence and bombing missions beginning on March 23.

Spain provided four EF-18s and two CN-235MPA maritime patrol aircraft, which helped enforce the no-fly zone and supported the naval blockade. This support for the new Libyan government is unlikely to be the last combat use of the F/A-18 for a number of reasons.

The rugged and flexible aircraft has proved itself during a wide range of missions in a great variety of circumstances, climates and conditions. It has also proved to be extremely reliable, even when operating continuously and at long ranges. Even as many of the early versions have been replaced by the larger Super Hornets, there are still 337 in service with the US Navy as of the beginning of 2014. Alongside these are another 227 in the US Marine Corps, the last not being set to retire until after 2020.

■ Words: *Tim Callaway*

Four of the upgraded EF-18s of the Spanish Air Force took part in Operation Unified Protector to enforce the no-fly zone over Libya and support the naval blockade. **Luigino Caliaro**

From the cockpit

Eagles and Hornets in Europe

Canadian units in Germany during the 1980s were converted to the CF-18 and both they, and US units stationed nearby, were keen to learn about its abilities. F-15C pilot Robert I. 'Scout' Winebrenner was among them...

MY flying experience was primarily in the F-15C Eagle in Europe, my first tour being based at Bitburg Air Base in Germany's Eifel region in the early 1980s. Beginning in 1984, the Canadian squadrons in Germany were being equipped with the CF-18 after many years flying the CF-104.

By 1986, all the Starfighters had been replaced. My first exposure to the Hornet was flying DACT against the CF-18s at CFB Baden-Söllingen. The Tiger Squadron' partnership between my squadron, the 53rd Tactical Fighter Squadron (TFS) and 439 Squadron in Söllingen contributed to this cooperation. Although there were a few new pilots who came directly out of pilot training to the CF-18, most had converted from the CF-104 – in which I also had a ride at one point.

Although their conversion training gave the CF-18 pilots a small taste of the air-to-air mission in a modern fighter, the pilots were clearly keen to learn more about it, especially in the Central European context, and we did some out-and-backs from Bitburg to Söllingen for DACT with the CF-18s including some extended brief and debrief time.

You simply don't overwrite years of air-to-ground thinking in the Starfighter with a handful of syllabus missions during

conversion training. We were delighted to help, and were very much interested ourselves in learning what the Hornet could do.

The CF-18 was very much like the F/A-18A with a few interesting differences. The CF had a bright identification spotlight built into the port fuselage just forward of the cockpit, a different ejection seat, and a fake cockpit outline painted on the bottom. Most of us were quite enamoured with the latter. What a great idea! That doubt in an enemy's mind whether you were turning toward him or away from him at first glance might make a big difference.

Some Eagle pilots mockingly suggested we should paint our aircraft like submarines: "Just think: That brief hesitation as he thinks 'What's that submarine doing up here?' may be all the advantage you need!"

"Envious," I mused. I, for one, liked the fake canopy. At first, the CF-18 pilots seemed very intent on utilising their Track While Scan (IWS) radar mode, even to search the airspace. Although somewhat different, the Eagle was equipped with TWS as well, but we never used it as a search tool.

Actually, we were very careful about how and when we used it at all, and for how long: A brief look after sample locking at long distance perhaps, to check for multiple targets within resolution cell. The problem in the Eagle was it narrowed the view of the outside world down to a tiny picture. In the Hornet, it would 'keep track' of one target while moving the antenna away in the near vicinity to look for more.

In both cases, the early TWS implementations were not at all good in dynamic environments. Once targets started moving, the display did not keep up in a timely fashion. You could fly along naively believing that you still had 'the picture' and what was displayed on your scope was not even remotely close to the truth. We were big believers in disciplined search and sort techniques, and not so much in this new-at-that- time radar processing wizardry.

This is exactly what happened during the first few meetings with the CF-18s. We found out in the debriefs that they were using TWS to search, and it was definitely not helping them. They were not getting BVR missiles launched when they needed to be launched, and then came into the merge with a situational awareness deficit. We had some long discussions about this, and flight debriefs ended up in larger venues with half the squadron in attendance. In subsequent sorties, using what they called Range While Search, they had much better success. TWS got better over the years, but in the mid-80s, it was not quite ready for Prime Time. Ten years later, TWS modes in both aircraft were not only much better, but were an important part of multi-target AIM-120 employment.

Since the CF-18s were shooting essentially the same weapons (Sparrows and Sidewinders) at about the same ranges, tactics as well as sorting and targeting execution determined the outcome of the battle. Even after the aforementioned radar sorting and targeting tasks were addressed, the Hornet pilots were very focused on maintaining visual mutual support in these engagements.

A worthy aim, to be sure. But not at the expense of allowing the enemy to drag you out in one direction while another swings your 3-9 line from the opposite direction. We politely pointed out that you are not providing any mutual support at all if you are dead at the merge.

To be fair, we saw the very same thing from Phantom or Viper units whose primary mission was strike or attack, and who therefore did much more air-to-ground than air-to-air. But the CF-18 Hornet pilots adapted quickly. In subsequent missions, it very much had the feel of a 2v2 similar ACT mission with everyone doing the same thing at the same time.

During these first encounters, there were not a lot of clear 1v1 situations that developed into slow speed knife fights. However, from the close-in manoeuvring that I observed, the Hornet's nose-pointing ability at slow speed was every bit as good as the Eagle's if not better. I thought the Eagle might enjoy a slight sustained turn rate advantage, but with our engines being detuned as much as they were to save wear and tear, it was anyone's guess.

I also noted that the APG-65 radar in the Hornet had a 70° gimbal limit, where the Eagle and most other fighters had only 60°. This limit is essentially how far off boresight a target can be before the radar reaches physical limits and breaks lock. This is important because it can translate into an F-Pole advantage.

F-Pole is the distance between the launching fighter and the target aircraft at missile impact. To increase F-Pole for semiactive radar guided missiles, fighters can turn away after launch and put the target near the edge of the scope. With no changes to airspeed, a 60° turn ➤

A 36th Fighter Wing F-15 Eagle on take-off from its home base of Bitburg in Germany. **USAF**

53rd Tactical Fighter Squadron pilots on an exchange visit to Orange in November 1982. Officer Commanding was Lieutenant Colonel Rowdy Lewis standing third from the left. The author, Robert 'Scout' Winebrenner, is standing in the front row immediately below the star of the national markings. **Robert I. Winebrenner**

The fake cockpit on the underside of the nose of the Canadian CF-18A serves to confuse an opponent as to the direction the fighter is turning. **RCAF**

The tiger badge of the 53rd Tactical Fighter Squadron. **Editor's collection**

The CF-18 replaced the CF-104 in service with the Royal Canadian Air Force. These are two Aerospace Engineering Test and Evaluation Aircraft in the early 1980s, when the CF-104 was nearing the end of its 25-year career. **RCAF**

The Hughes, now Raytheon, AN/APG-65 radar was mounted in the nose of the F/A-18A and B as well as the CF-18. **Raytheon**

decreases the fighter's forward speed component toward the target by half.

That's cosine of 60° for those who would like to check the maths. At 70°, we are down to .342 – and that is a certain, measurable advantage in the semi-active radar missile arena Actually achieving that in a tactical environment is tricky: normally a pilot would give himself about a 5° buffer just to be sure not to hit gimbal limits and trash the missile. But that is still a difference of 55° (.5736) for the Eagle to 65° (.4226) for the Hornet.

I also noticed the Hornet pilots referred to their two radio sets as the Left and the Right. Quite logically, considering the position of the control heads up front, just below the HUD. That's where the Eagle had one radio, which we referred to as the Main, which was also our Have Quick frequency agile radio set.

The other radio control was aft of the throttles, and we called it the Arne So if Eagles and Hornets were flying together, we needed to agree on which radio corresponded to which. That knowledge came in handy later.

LARGE FORCE EMPLOYMENT

Following my second tour in the Eagle with the 32TFS in Soesterberg, the Netherlands, I again had frequent contact with the CF-18s as an instructor at AAFCE's (later AIRCENT) Tactical Leadership Programme (TLP). During the courses, participants were put in situations that required them to work as teams with dissimilar aircraft, utilize the relative strengths of each, and keep the plan simple enough to be executed even in the face of communication difficulties.

When doing planning for large force employment in such exercises involving several types of fighters, we used a rule of thumb that the Belgian or Dutch F-16s were 'half an F-15' – the empty weight was approximately half the F-15's, it had one of the same type of powerplant, and carried half the fuel. So, for example, if an F-16 pilot signalled 3000lb fuel remaining, that was essentially equivalent in most respects to an F-15 having 6000lb remaining.

After CF-18s started appearing on the scene, we needed another rule of thumb: two-thirds was a good approximation. A Hornet's weight, fuel reserves, fuel flow, etc. were about two-thirds of an F-15's. These rules of thumb served us well when participants were put in situations requiring them to work together as teams and to promote mutual understanding during TLP missions.

To enable the TLP staff to observe and later reconstruct and comment on the missions, units that had two-seat variants were asked to bring one to TLP. We would normally have one TLP staff member embedded in the air-to-ground package and another with the air-to-air formations. On the air-to-air side, the two-seat variants were typically F-16s, F-15s, and CF-18s, with the occasional Mirage 2000.

Therefore, my TLP observation flights were mostly in the F-16 and the CF-18. My

The front cockpit of a CF-18A. showing the centre radio panel just below the Head Up Display (HUD). **RCAF**

The badge of the 32nd Tactical Fighter Squadron, the Wolfhounds. **USAF**

The badge of the Allied Air Forces Central Europe Tactical Leadership Programme. **USAF**

One of the 32nd Tactical Fighter Squadron F-15Cs armed with AIM-7 Sparrows and AIM-9 Sidewinder missiles. The unit was based at Soesterberg in the Netherlands. **USAF**

A Royal Canadian Air Force CF-18A fires an AIM-7 Sparrow missile. This and the AIM-9 Sidewinder were the main armament of both the CF-18 and the author's F-15. **RCAF**

experiences flying in the two aircraft were completely different. In the F-16, especially the early 'A' blocks with the radar scope between the legs, I felt a little bit like a foreign object, at least for the first few flights. These flights occurred even before my tenure at TLP.

Yes, it also had HOTAS – hands on throttle and stick – with the ability to perform myriad tasks without moving the hands away from the stick and throttles. But which fingers (or thumb) controlled what was completely different. It's all learned behaviour, I suppose, but coming from an F-15 background, it was certainly not intuitive for me. Even after several flights, although I knew what to expect and was familiar, I was never really comfortable.

Then came my first flight in the CF-18, during which I had a completely different reaction. Except, of course, for the strapping in part, which was made exceedingly complicated by the Canadians' ejection seat selection.

One pilot remarked to me that he doubted they could make five-minute air defence scramble responses because it took that long just to strap in! But that small hurdle overcome, a glance around the cockpit was a very welcoming experience for this F-15 pilot.

Everything was where it was supposed to be, in my mind. The switches, knobs and gauges had a familiar look. Clearly, the fact that both aircraft originated from the same St Louis livery had something to do with it, but it went further than that. I was comfortable there.

The front seater was a course participant – it was his mission. I was there to observe and assist reconstruction. That notwithstanding, he gave me plenty of stick time, including all the way out and all the way back, which gave me ample opportunity to play with the radar and kill a few random targets that approached our flight path, fly tactical and close formation, and back at Florennes, fly the patterns and everything up to the last 50ft or so before landing. At that point, he took the aircraft back and executed the landing, saying: "You probably want to flare this, but you don't. Just keep it steady and fly it onto the runway. It's built for it."

Back to the chocks, shutdown, forms, etc, all standard. But I was exuberant. "You know, this could be completely over-the-top misplaced confidence on my part, but after that flight, I have the feeling that I could walk out there, fire one up, and go out and fly the airplane, run the systems and even employ it tactically... just like that."

The Canadian pilot shrugged and responded, "Well ... MacAir, you know. Let's go get a beer." I wondered if he would have that same feeling flying in an Eagle.

That was the first of many flights in the CF-18, and my opinion didn't really change that much, but my comfort level only increased, if that is possible. I still can't say I liked the strapping in bits, but by about the third flight, I could do it myself correctly and confidently. I was also pleased that I could wear my own helmet and G-suit only the end connector of the oxygen hose needed changing. Easy.

I admit there were some things I ➤

Pilots of the 32nd Tactical Fighter Squadron with their Wolfhound mascot. The author is in the centre row, third from the right. **Robert I. Winebrenner**

liked better about the Hornet: the displays, for example. Even though most Hornet pilots put their radar display on the right, it was flexible. I put mine on the left, and felt right at home. The moving map was also brilliant, but maybe a bit superfluous for the air-to-air mission of the F-15C, and it took up precious cockpit real estate. I liked the slightly larger HUD.

The cockpit had a generally more modern appearance. The 70° gimbal limit was great. The stick grip was also well designed with the extra control knob (the 'castle' switch). As it turned out, the Multi-Staged Improvement Programme (MSIP) modification to the F-15C included a multi-function colour display (MFCD) in place of the earlier analogue armament panel. It performed this function but doubled as a JTIDS Joint Tactical Information Distribution System) terminal.

The Eagle also got the Hornet stick grip with the castle switch to run that MFCD. I also liked the very similar flight performance in the slightly smaller size of the Hornet, but that comes at a price in terms of weapons carriage capacity.

Naturally, there were a few things that I didn't like as well, beginning with the radar. Not that the Hughes APG-65 was a bad radar – far from it. But the narrower beam width and brute force of the F-15's APG-63 was superior for most air-to-air situations. Moreover, the APG-65 was optimised for over-water operation, and incorporated some rather severe side-lobe suppression techniques which drastically reduced detection range if the Hornet was at lower altitude over land.

The Eagle's radar did similar things, but not anywhere near to the same extent. The Eagle's radar also did a better job dealing with Electronic Counter Measures (ECM). The APG-65 had some clever algorithms and did a decent job. The Eagle's APG-63 used similar techniques, but it also had brute force. More power.

I also thought the view in the Eagle was slightly better. There was just a bit more rise in the canopy to be able to look toward 6 o'clock, and in the Eagle I didn't have to roll to look down over the side, where the Hornet had the long wing strakes. The latter was still a factor in the front seat, but it was worse in the back. And lastly, in really bad, disorientating weather conditions, I preferred the 'head down' conventional flight instruments in the Eagle.

When things get rough, I think it is easier to fight off spatial disorientation and vertigo by looking inside and concentrating on conventional flight instruments instead of viewing that information through the HUD.

Royal Canadian Air Force CF-18s were stationed in Germany with 409,421 and 439 Squadrons from 1985 to 1993. While in Germany the Hornet was used for battlefield air interdiction, tactical strike. close air support and air defence. Almost every NATO flying unit in Central Europe has flown by Hohenzollern castle in Baden-Württemberg. as seen here. **RCAF**

MIXED FORCE FIGHTER OPERATIONS

There was one more incident that was one of the highlights of my tour at TLP. We once had both F-15s and CF-18s on the course, and after several attempts and changes, the TLP mission for the day was scrubbed owing to weather.

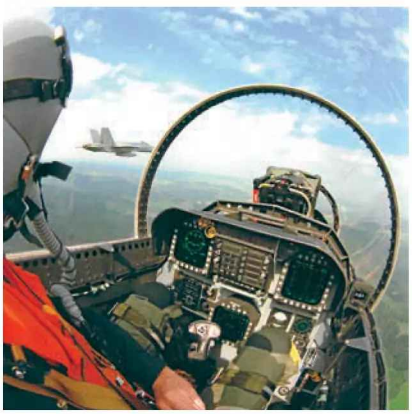
Under such circumstances, it was permitted for me to take one of the F-15s and fly a mission for proficiency and currency in the afternoon. Another staff member in the air-to-air shop was Captain Greg 'Claw' Morris, a CF-18 pilot. So we decided to do a mission together.

After checking the applicable national regulations, we determined that it was not allowed to fly dissimilar close formation. But there were no prohibitions on dissimilar tactical formations. So we found the best weather in Low Fly Area (LFA) 7 in southern Germany, and briefed up a low altitude VFR ingress through France at slower speed to save fuel, intercepts on targets of opportunity in LFA7, and a high-altitude recovery to individual instrument approaches at Florennes.

Claw would lead us out, taking advantage of the Hornet's better navigation equipment, I would then lead the tactical portion and the recovery, with the understanding that

The author flew Tactical Leadership Programme observation flights in the two seat CF-18B. **RCAF**

Leadership training in dissimilar large formations in the Tactical Leadership Programme involved a number of types, often those seen here, the F-15, F-16 and F-18. **USAF**



The view from the rear cockpit of a Royal Canadian Air Force CF-18B, a layout the author was immediately at home and comfortable with. **RCAF**

A CF-18A releases a countermeasures flare in a tight turn. The manoeuvrability and ability to 'point the nose' of the aircraft was a facet the author appreciated. **RCAF**

The cockpit of a Belgian F-16, including the radar display mounted down between the pilot's legs. **wingsovereurope.com**

The cockpit of an F-15C, the radar display, hooded to prevent reflections, is to the left of the upper centre radio panel. the warning receiver display is to the right. The new multifunction display and JTIDS terminal is on the lower left of the main panel. **USAF**

The cockpit of the CF-18B, the leading-edge root extensions mean the pilot has to roll the aircraft to see downwards. **RCAF**

the tactical lead could switch back and forth depending on the situation. As it turns out, it wasn't all that necessary.

After uneventful ground operations, Claw led us out of the chocks, we lined up and I took 20 second spacing on an instrument departure until we were both in relatively clear air, able to cancel IFR and proceed en route. I joined to a 6000ft line abreast position. It was also a very easy transit through France and Baden-Württemberg, and approaching LFA7, I took the lead and we changed frequency to CRC Lauda, callsign Strawbasket.

It was LFA7 as I knew and loved it. The usual players were there: Neuburg Phantoms, Memmingen Tornados, and a couple of Vipers that left as quickly as they arrived. We had more engagements – or I should say tactical intercepts – than I could count, and Strawbasket was making some great and timely calls.

We worked together well and the aircraft were very compatible. But if it's possible to sum up all the intercepts, I would say with little exaggeration that everyone saw me, and no one saw Claw. In the terminal phase of the intercept, invariably our intended victims would react and turn into me, scanning the horizon for the 'second Eagle' – leaving Claw with more close-range belly Sidewinder shots than he probably cared to take. It was too easy for him!

The best was when two Söllingen CF-18s pitched up, and the same thing happened. They turned into me, leaving Claw squarely behind them. He quickly switched frequencies to squadron common on the backup radio and told his buddies to check six!

"Hey, what are YOU doing back there?"

"I'm with the F-15! Fox 2 on both of you!"

I think there might be a lesson here about 'glomming on' to the first and biggest, and not seeing the others. Maybe.

We both hit bingo about the same time, and I arranged a climb and handoff as Claw joined to ... no closer than 500ft. The Eagle seemed to climb a little faster, so I gave him a few percent of throttle and then it was all right. The recovery was also uneventful.

When approaching Florennes, I cleared Claw off on separate vectors. I sent him down first after applying the 2/3 rule of thumb, as he was a little lower on fuel than I was.

Simply because of its uniqueness, that mission stands above the others as my most memorable in LFA7, and I assure the gentle reader, there were quite a few.

After 26 years in the air force, I retired in 2005. Now my only exposure to the Hornet is watching the US Navy Blue Angels practice over my home in Pensacola. I did note disappointedly that they don't have the fake canopy.

■ Words: *Robert I. 'Scout' Winebrenner*

The F/A-18 abroad

The success of the Hornet in the export market

Other than the United States Navy and Marine Corps, there are seven other armed forces around the world that operate the first four versions of the Hornet.

As mentioned earlier, McDonnell Douglas achieved some early successes with export sales of its version of the Hornet, largely to air arms that did not even own or operate an aircraft carrier, such was the excellent performance of the aircraft.

While this success effectively killed the F-18L land-based version programme being offered by Northrop as its part of the partnership, it did extend the production lines at both companies as Northrop was a major subcontractor, building the fuselage aft of the cockpit and the twin fins.

The last of the 1480 F/A-18A, B, C and D models built were all weather attack versions of the F/A-18D delivered to the US Marine Corps in 2000. Aside from the seven nations listed here, 10 more countries evaluated the F/A-18 but purchased other types, and one more, Thailand, ordered the aircraft but had to cancel it due to the financial crisis that struck the region in the 1990s.

All of the exported Hornets were acquired with the US Navy managing the purchases using the US Foreign Military Sales (FMS) mechanism, with the exception of those for the Royal Canadian Air Force, which purchased its Hornets directly from McDonnell Douglas. The countries are listed here in the order that they acquired the Hornet.

CANADA

By the mid-1970s, the Royal Canadian Air Force (RCAF) was operating three different types of fighter and fighter-bomber, supporting its commitments as a member of NATO. By this time, three RCAF squadrons of Lockheed CF-104 Starfighters were operating in Europe in the ground-attack and reconnaissance roles while three more were flying McDonnell CF-101B Voodoo two seat air interceptors as part of Canada's commitment to the North American Aerospace Defence Command (NORAD).

Lastly, two squadrons of Canadair CF-116 Freedom Fighters, the licence-built version of the Northrop F-5 often referred to as the CF-5, were based in Canada as a NATO rapid deployment force in case of hostilities in Europe. By 1977 the first two of these types had been in service for 17 and 18 years respectively and were fast requiring replacement.

To this end the Canadian Government began the New Fighter Aircraft (NFA) competition, initially to replace all three types, although the

Four Royal Canadian Air Force CF-18As showing the fake canopy painted on the underside of the nose. Note the targeting pod on the port fuselage pylon of each aircraft. **RCAF**

CF-5 would eventually be retained. The new aircraft had to be an existing design with proven technologies and include an offset advantage to Canadian industry. Seven types were considered, which by 1978 had been whittled down to the General Dynamics F-16, the McDonnell Douglas F/A-18 and the Northrop F-18L.

The F-16 was discounted because the RCAF's operations over the Arctic and northern oceans favoured a twin engined aircraft as a safety factor. At the time, despite being ideal for the task, the F-18L had yet to be built. Northrop had still not received its first order for the type, so it was considered too great a risk. In April 1980, the F/A-18 was selected as the winner of the NFA competition and an order placed directly with McDonnell Douglas for 98 single seat CF-188As and 40 CF-188B two seat versions. The aircraft are seldom referred to by these designations and are commonly known as CF-18A and Bs.

The CF-18s differed little from the F/A-18, retaining the undercarriage, arrestor hook and folding wings of the naval aircraft as these facets of the design were well suited to the rugged Canadian operating environment, particularly in winter. The ACLS was replaced with an ILS/VOR as would be the case with the Australian aircraft a few years later. The cannon bay door on the port side of the nose was modified to mount a 600,000 candle power spotlight for use in identifying other aircraft at night, air defence being a major part of the CF-18s role.

Lastly, the underside of the nose was painted with a fake canopy, the aim being to disorient an opponent regarding which way the Hornet was turning. The first CF-18A flew at the St Louis plant on July 29, 1982, and the first two aircraft were delivered to 410 (Operational Training Unit) Squadron at Canadian Forces Base (CFB) Cold Lake on October 25. The final single seat aircraft was delivered in September 1988, by which time the CF-18 was equipping a total of eight RCAF squadrons, three of which, 409, 421 and 439 Squadrons, were based at Baden Söllingen in Germany with 1 Canadian Air Group.

Like the early US Navy and Marine Corps Hornets, the RCAF Hornets suffered from the early problems with fatigue cracking in the fins. Like their American counterparts, this was first cured by local strengthening in 1984, followed in May 1988 by the addition of the now familiar fixed plates atop the leading-edge root extensions (LERX).

The RCAF made its first combat deployment with the CF-18 when 26 of the Hornets based in Germany were sent to Doha in Qatar in 1991 to take part in the Gulf War, a deployment called Operation Friction. The RCAF Hornets flew over 5700 hours of combat air patrols, escort missions and ground-attack sorties during the build-up to the conflict and the short war. ➤

Canadian CF-18s were based at Baden Söllingen in Germany with 1 Canadian Air Group and included 409, 421 and 439 Squadrons. **RCAF**

Between August and November 1997, CF-18s were sent to Aviano air base in Italy to support NATO peacekeeping forces in Bosnia and Herzegovina by flying armed deterrent patrols. The continuing violence in the former Yugoslavia meant that 18 CF-18s were to return to Aviano in June 1998 and were to remain deployed until December 21, 2000, flying combat air patrols over Bosnia and Herzegovina and Kosovo during that time.

While on this deployment, the CF-18s of 441 and 425 Squadrons took part in Operation Echo, RCAF bombing missions in support of NATO's Operation Allied Force between March 24 and June 10, 1999, during the Kosovo War. In that period, the Canadian crews flew 684 sorties, using both guided and unguided bombs, a remarkable 10% of all NATO bombing missions flown despite being just under 2% of the Allied air power committed to the region.

It was as a result of these deployments that the Incremental Modernization Project (IMP) was funded in 2001 to extend the air-to-air and air-to-ground capabilities of the CF-18 fleet. In 2002, a contract was agreed with Boeing, which had merged with McDonnell Douglas in 1997, to upgrade the CF-18A and Bs to the equivalent of the F/A-18C and D. In this upgrade, the AN/APG-73 radar replaced the original -65 unit bringing with it more advanced modes and enhanced low level capabilities.

The mission computers, their associated stores management system and MIL-STD-1760 databus were all upgraded, which not only tremendously increases the data processing speed and power of the CF-18 but also brings new flexibility to the range of weapons the aircraft can carry. This information processing capability is further extended with the addition of the Link 16 tactical data system to allow data sharing with Allied aircraft and other units.

In addition to these systems, the radios, flight data recorder and the electronic warfare and countermeasures suite were all upgraded, along with the introduction of a GPS/INS navigation suite. Inside the cockpit the pilot is presented with new flat panel LCD displays and a night vision imaging system allied to the JHMCS to improve information presentation and response time.

The new Lockheed Sniper XR Advanced Targeting Pod provides infrared and TV imagery and incorporates a laser spot tracker and target marker. All of these improvements mean the CF-18s are now capable of carrying the AIM-120 AMRAAM air-to-air missile and the latest LGB and JDAM series of air-to-ground weapons. Altogether 62 CF-18As and 18 CF-18Bs were upgraded from the existing fleet, the IMP taking place in two phases.

Current Royal Canadian Air Force CF-18A and B units

No. 425 Alouette Tactical Fighter Squadron, part of 3 Wing, CFB Bagotville, Quebec No. 409 Nighthawks Tactical Fighter Squadron, part of 4 Wing, CFB Cold Lake, Alberta No. 410 Cougars Tactical Fighter (Operational Training) Squadron, part of 4 Wing, CFB Cold Lake, Alberta AETE (Aerospace Engineering Test Establishment)

A side view of a McDonnell Douglas CF-18 of the Royal Canadian Air Force. **Keith Draycott**

The cockpit of a Royal Canadian Air Force CF-18A. **Ariel Shocron**

Phase I was completed in 2006, the final Phase II aircraft was delivered in March 2010. Most recently, the RCAF deployed seven CF-18s to the Italian Air Force Base at Trapani in Sicily. Known as Operation Mobile, these aircraft and crews were provided to enforce the no-fly zone over Libya as part of the NATO forces acting on behalf of the UN.

Between March 23 and November 4, 2011, the CF-18s flew air defence and bombing missions to protect the civilian population from attacks by their Government during the Libyan Civil War.

In 2020, Phase I of the Hornet Extension Project (HEP) commenced to modernise Canada's remaining fleet of 94 CF-18A/Bs. This included further compatibility with the AIM-120D AMRAAM as well as the replacement of obsolete transponders, new Honeywell GPS/INS systems, upgraded radios, upgraded mission computers and updates to the Sniper pods.

Phase II of HEP was then applied to the best 36 CF-18A/Bs of the fleet, alongside the delivery of 50 AIM-9X Sidewinder Block IIs, 38 CA/APG-79(V)4 AESA radars, 46 F/A-18A wide-band radomes and upgrades to the Advanced Distributed Combat Training System.

It was expected that this much-upgraded fleet would eventually be replaced by F-35s – or possibly Saab Gripens – from 2028.

AUSTRALIA

In 1963 Australia had begun building the Mirage IIIO under licence, the last aircraft being delivered in 1968. With delays to the selection competition for a replacement, in 1979 the Mirage fleet was subject to a life extension programme which included new wings, upgraded engines and avionics and the addition of a laser designator for use with laser guided bombs.

In 1980, the procurement of a replacement was restarted and a ➤

A pair of CF-18Bs of 410 Squadron of the Royal Canadian Air Force. Like the single seat aircraft, the two-seat versions also have the fake canopy on the underside of the nose. **Luigino Caliaro**

A CF-18B of 410 Squadron resplendent in the unit's 60th anniversary markings, including their former mount, a night fighter version of the de Havilland Mosquito, on the fin. **RCAF**

number of aircraft were considered to replace the Mirage fleet, including the McDonnell Douglas F-15 Eagle and F-18A Hornet, Panavia Tornado, Dassault Mirage 2000 and General Dynamics F-16. The F-15 was expensive and at that time did not have the close support capability the Royal Australian Air Force (RAAF) required, while the Tornado lacked the necessary air-to-air capability.

The Mirage 2000 and F-16 were both single engined aircraft, which, for an air force that operated regularly over the expanses of the southern oceans, were not ideal candidates from the start. The F/A-18 fitted the bill in all major respects, but the technology was still immature. The RAAF asked that the decision be deferred for a year to allow the airframe and avionics to be further developed, the Hornet being officially selected on October 20, 1981.

The procurement of the aircraft was effectively managed by the Australian Government, which ensured that the purchase included the extensive

A side view of a McDonnell Douglas F/A-18B, A21-115, of 2 Operational Conversion Unit of the Royal Australian Air Force. **Keith Draycott**

An F/A-18 Hornet displays the stunning 20th anniversary paint scheme of aircraft A21-26 while performing an aerobatic display over Tomaree Heads, New South Wales. **RAAF**

A RAAF F/A-18 Hornet from No. 2 Operational Conversion Unit in transit to RAAF Base Williamtown from Temora in New South Wales. **RAAF**

involvement of Australia's aviation industry and built experience and support within the air force and a local spares supply for the intended life of the airframes. An order was placed for 57 F/A-18As, initially known as AF/A-18As, and 18 of the two seat AF/A-18Bs. The single seat aircraft were given the serials A21-1 to A21-57, the two seaters being A21-101 to A21-118. The initial A of these early designations was soon dropped as the aircraft were extremely similar to their US equivalents with the exception of the following detail changes.

To fulfil all the major roles required by Australia, its F/A-18s were equipped from the outset to carry a reconnaissance pod and were fitted with a high frequency (HF) radio as well as the standard VHF/UHF units. The Automatic Carrier Landing System (ACLS) would not be required so was replaced with a combined Instrument Landing System and Very High Frequency Omnidirectional Radio Range (ILS/VOR) for bad weather or night instrument approaches and navigation.

An Australian fatigue data analysis system was fitted to monitor the airframe life and the cockpit video and voice recorders were upgraded. The avionics suite was assembled by British Aerospace Australia Ltd, while the 16,000lb (7258kg) thrust General Electric F404-GE-400 turbofans were constructed by the Commonwealth Aircraft Corporation at Fishermans Bend.

The first two aircraft, F/A-18B A21-103 and A21-104, were assembled in Australia, with A21-103 being delivered to the RAAF on May 4, 1985. These were followed by two built by McDonnell Douglas, A21-101 and A21-102, delivered on May 17, 1985, after testing and evaluation in America. The remainder of the airframes were assembled by the Government Aircraft Factory at Avalon which was later renamed Aerospace Technologies of Australia (ASTA).

F/A-18 A21-44, a 75 Squadron Hornet, prepares to drop 10 Mk 82 500lb bombs during exercise ACES NORTH. **RAAF**

The only major external change to the airframe was the removal of the catapult attachment arm from the front of the nosewheel leg. However, early testing showed that this had a marked effect on nosewheel shimmy, so it was replaced with a nonfunctioning version which cured the problem.

The first Australian assembled F/A-18A made its maiden flight on June 3, ➤

A formation of F/A-18 Hornet aircraft from No. 2 Operational Conversion Unit fly over RAAF Base Williamtown. **RAAF**

An EF-18A of the 15th Fighter Wing of the Spanish Air Force pulls through a loop. **Luigino Caliaro**

1985, with the first deliveries being made to operational squadrons of the RAAF in August 1986. Pilot training had already begun with the introduction of the first two McDonnell built F/A-18Bs and two more assembled in Australia into service with 2 Operational Conversion Unit (OCU), so the force was quickly built up to its intended strength of three squadrons. The last of the Mirage IIIOs were withdrawn from RAAF service in 1988 and 50 of the survivors were sold to Pakistan.

Since its introduction into service, the RAAF F/A-18 fleet has undergone a series of equipment upgrades between 1999 and 2007, roughly analogous to the US Navy's F/A-18C standard. The upgrades include the Raytheon AN/APG-73 radar replacing the earlier -65 system, along with upgraded defensive aids and electronic countermeasures, radios, GPS and Inertial navigation systems (GPS/INS) and mission computers.

The cockpit improvements have included new displays, the tactical data sharing Link 16 system and the Joint Helmet Mounted Cueing System (JHMCS). Lastly, the AN/AAS-38 Nite Hawk targeting pod introduced in the early 1990s has been replaced by the AN/AAQ-28(v) Litening system. These upgrades enable the Australian Hornets to carry the AIM-120 AMRAAM and AIM-132 ASRAAM air-to-air missiles, as well as the JDAM and, since 2011, the AGM-158 Joint Air to Surface Stand Off Missile (JASSM).

Along with the avionics upgrades, the RAAF aircraft also received all of the US airframe modifications such as the vortex plates above the leading-edge root extensions and strengthened fins. The fleet underwent a life extension programme to rectify all damage from service use, 10 of the aircraft receiving new the Australian Hornets to carry the AIM-120 AMRAAM and AIM-132 ASRAAM air-to-air missiles, as well as the JDAM and the AGM-158 Joint Air to Surface Stand Off Missile (JASSM).

In early 2019 it was announced that 25 Australian Hornets would be sold to Canada for $90 million and the last remaining examples were officially retired on November 29, 2021. In 2023, there were discussions about selling or transferring the retired Hornets to Ukraine but this offer was declined by the Ukrainians who wanted to focus on getting the F-16 into service instead.

As part of the deal for 60 F/A-18As and 12 F/A-18Bs, the Spanish aerospace manufacturer CASA became a subcontractor to McDonnell Douglas, building a variety of airframe components including the leading edge root extensions, tailplanes and rudders.

The aircraft were redesignated as EF-18s by the manufacturer and in Spanish service they are referred to as the C.15 for the EF-18A and CE.15 for the EF-18B.

In all major respects, the Spanish Hornets were similar to their US Navy counterparts, the first EF-18 being delivered to Spain in February 1986, having

first flown on November 22 the previous year. The next four aircraft delivered in July 1986 were all two seaters, these being brought into service first to enable pilot training to begin. Deliveries of the first order continued through to 1990, the EF-18As being given the Spanish Air Force serials of C.15-13 to C.15-72, while the EF-18Bs were CE.15-1 to CE.15-12.

During the 1990s, two changes were made to the Spanish Hornet fleet which greatly extended their capabilities. The first of these was a rolling programme to upgrade the existing aircraft to the F/A-18A+ and B+ standard, the equivalent of the US Marine Corps aircraft with radar and avionics similar to the F/A-18C and D. The upgrade also included the acquisition of AN/AAS-38B NITE Hawk targeting pods.

Secondly, in 1995, an additional 24 F/A-18As were purchased, these being retired US Navy aircraft. The aircraft were refurbished and upgraded to the F/A-18A+ standard, being delivered between December 1995 and December 1999. The Hornet is operated in Spain in four main roles, those of all weather interceptor fighter, tactical air support, maritime strike and suppression of air defences.

Like their Canadian counterparts, Spanish Hornets have been deployed operationally as part of their NATO commitments, operating from Aviano air base in Italy in a variety of roles to support NATO peacekeeping forces in Bosnia, Herzegovina and Kosovo. Eight EF-18s also flew bombing missions in support of NATOs' Operation Allied Force between March 24 and June 10, 1999, during the Kosovo War.

In 2011, four EF-18s flew missions to enforce the no-fly zone and protect the civilian population during the Libyan Civil War as part of the NATO forces acting on behalf of the UN. At the beginning of 2026, the Spanish Air Force still had 69 F/A-18As and 12 F/A-18Bs in service

Current Spanish Air Force F/A-18A and B units:
15th Fighter Wing (Ala de Caza 15) – 151, 152
and 153 Squadrons – Zaragoza Air Base
12th Fighter Wing (Ala de Caza 12) – 121 and
122 Squadrons – Torrejón Air Base
46th Wing (Ala 46) – 462 Squadron – Gando Air Base on the Canary Islands

KUWAIT

The Al Quwwat Aj Jawwaiya Al Kuwaitiya, the Kuwait Air Force, had been operating the Dassault Mirage F.1 and the Douglas A-4KU Skyhawk up to the Iraqi invasion of August 2, 1990. After the Gulf War in 1991, the air force underwent a reorganisation and re-equipment programme, which included an order for 32 F/A-18Cs and eight F/A-18Ds to replace the earlier strike fighters.

The Hornets equipped the 9th and 25th Squadrons based at Ahmed al Jaber Air Force Base, where units of the US Marine Corps were based alongside them during Operations Southern Watch and Iraqi Freedom. Aside from these operations, the Kuwaiti F/A-18s have been involved in a number of exercises with other air forces in the Gulf region and operate in both the fighter and strike roles.

The Kuwaiti aircraft are fitted with the spotlight mounted in the cannon bay door in the nose like the Canadian aircraft. One Kuwaiti F/A-18D crashed during training on October 9, 2024, with the pilot being killed. At the beginning of 2026, 27 F/A-18Cs and six F/A-18Ds remain in service with the Kuwait Air Force.

Three of Switzerland's F/A-18Cs over one of the stunning valleys of their home nation. **Swiss Air Force**

Swiss Air Force F/A-18s participate in events all across Europe. This aircraft is landing at the Royal International Air Tattoo at Fairford in the UK. **Keith Draycott**

Switzerland

The Swiss armed forces began assessing options to replace the country's ageing fleet of Mirage IIIS and F-5E Tiger II aircraft in 1985. Potential candidates included the Northrop F-20 Tigershark and Saab's Gripen, as well as the Dassault Rafale and Mirage 2000. Eventually however, the choice was narrowed down to two leading contenders: the F-16 and the F/A-18.

A fly-off was conducted and a final report was delivered in May 1988 which concluded that the Hornet was the winner. The competition was briefly reopened so that the MiG-29 and Mirage 2000-5 could be reviewed before a $2.5 billion contract was awarded to McDonnell Douglas on June 17, 1992, for 26 F/A-18Cs, eight F/A-18Ds and a substantial quantity of spare parts.

A national referendum was then held on June 6, 1993, which called for the cancellation of the deal but the Swiss public just barely approved it. McDonnell Douglas manufactured the first two aircraft in ➤

the US – the two-seater J-5231 and single-seater J-5001 – but arrangements were made so that the rest could be assembled by Emmen-based Swiss Aircraft & Systems Enterprise Corporation (S+F).

The first Swiss assembled F/A-18D, J-5232, first flew on October 3, 1996, and the remaining aircraft were delivered between January 23, 1997, and December 2, 1999. There were some notable differences in the Swiss aircraft compared to the original design: the main wing spar was reinforced, elevating airframe life from 3000 to 5000 flying hours, and the AN/APG-73 radar system was installed to give better performance at high altitude.

ECM was provided by an integrated AN/ALQ-165 ASPJ and a light was carried for visual identification at night. Weaponry included four AIM-9P-5 Sidewinders, four AIM-120B AMRAAMs and the 20mm M61A1 cannon. No air-to-ground weaponry was acquired – since the Swiss Hornets' only role is air defence.

On April 7, 1998, a Swiss F/A-18D, J-5231, crashed due to pilot disorientation near Crans-Montana with the loss of both crew. A series of updates were made from 2001 to 2006, with more then following from 2006 onwards. These saw the installation of Link 16, a new mission computer, the Joint Helmet-Mounted Cueing System and the ability to carry the AIM-9X. Since then, further structural work has been carried out – extending airframe life still further, to 6000 flight hours. This should allow operation of the remaining fleet – 25 F/A-18Cs and five F/A-18Ds – into the mid-2030s.

FINLAND

Throughout the Cold War, Finland walked a fine political line between east and west, balancing military orders for aircraft between Soviet and European manufacturers. This led to a very mixed force, with Saab J35 Drakens serving alongside Mikoyan Gurevich MiG-21F-13s. Both of these types needed replacing by the end of the 1980s and a plan was begun ➤

F/A-18A A21-49 painted in 77 Squadron colours for the 70th anniversary celebrations. **RAAF**

The Lockheed Sniper XR Advanced Targeting Pod provides infrared and TV imagery and incorporates a laser spot tracker and target marker and is seen here mounted on a Canadian CF-18. **Jerry Gunner**

Below: A Finnish F-18C and F-18D Hornet refuel from a USAF KC-135 during interoperability training at Tampere, Finland. **USAF**

A pair of EF-18As of the 12th Fighter Wing of the Spanish Air Force. **Luigino Caliaro**

F/A-18 Hornets of 2 Operational Conversion Unit taxi to the runway at RAAF Base Townsville during Exercise High Sierra. **RAAF**

An F-18C of the Finnish Air Force landing at Fairford in Gloucestershire to take part in the Royal International Air Tattoo. **Keith Draycott**

A side view of a McDonnell Douglas EF-18B, C.15-58, of the 12th Fighter Wing of the Spanish Air Force. **Keith Draycott**

to acquire a mixed force of Soviet and European fighters.

The options open to Finland were limited by a number of treaties from the end of the Second World War, which, in 1990, were nullified by mutual agreement with the signatories to the Paris peace treaties.

However, with the dissolution of the Soviet Union in 1991 and the relaxation of political tensions, in 1992 the Finnish Government announced that it would be placing its first order for American fighters, an order that would not have been possible in the political climate prior to this point. After a comparative competition, the successful aircraft was announced as the F/A-18C and D models of the Hornet, but restricted to the fighter only role with no ground-attack weapons, so changing the designation to F-18.

The main reason for this was the mission of the Suomen Ilmavoimat, the Finnish Air Force, which was purely defensive in nature at the time, as well as not wishing to appear a threat to its neighbour to the east, which was in considerable turmoil. An order for 60 single seat and seven two seat Hornets was placed, which was later changed to 57 single seaters to remain within budget. The seven F-18Ds were built by McDonnell Douglas, the first six being flown to Pirkkala in Finland in November 1995. The first of the single seat aircraft rolled off the Patria Finaviatec assembly line in 1996, with the 57th aircraft being delivered in 2000.

The F-18s equipped all three regional Air Commands of the Finnish Air Force and were fitted with the ALQ-165 Airborne Self Protection Jamming pod (ASPJ). Finland joined both the European Union and NATO's Partnership for Peace programme and its F-18s have been regular participants in international exercises, with a Rapid Deployment Detachment of six F-18s being established in 2010 to assist in international crises.

The role of the air force has undergone major changes in the time the F-18 had been operational, so it was announced on December 7, 2004, that an upgrade programme would be undertaken to restore the multirole capabilities of the Hornets.

The first phase, known as Mid-Life Upgrade 1 (MLU 1), completed in 2006-10 and saw all 62 of Finland's F/A-18C/Ds fitted with provision for a helmet-mounted sighting system and given the ability to carry the AIM-9X Sidewinder. They also got a new identification friend-or-foe (IFF) system and tactical moving map capability.

The Mid-Life Upgrade 2 (MLU 2) programme was then completed from 2012 to 2016, adding NATO-standard secure datalink Link 16 and the ability to carry AMRAAM air-to-air missiles as well as precision-guided JDAM bombs and JSOW glide bombs. LCD cockpit displays, a new

One of the 32 F/A-18Cs ordered by the Kuwait Air Force in 1991, seen in the US prior to delivery. Note the spotlight mounted in the cannon bay door in the nose. **USAF**

A Royal Malaysian Air Force F/A-18D at TUDM Butterworth in north-western Malaysia on April 4, 2012.The aircraft was taking part in Exercise Cope Taufan, the biennial live-flying exercise between the US Air Force and RMAF, including dissimilar basic fighter manoeuvres and dissimilar air combat tactics training. **USAF**

An EF-18A carrying a mixed air-to-air and air-to-ground load. The Spanish Air Force uses the Hornet in the all-weather interceptor fighter, tactical air support, maritime strike and suppression of air defence roles. **Luigino Caliaro**

BOL chaff/flare dispenser and a GPS system was included too. The integration of the long-range JASSM missile was then completed in 2017.

A single F/A-18C, fuselage number HN-409, crashed near Rovaniemi Airport in northern Finland on May 7, 2025, reducing the fleet to 61 aircraft.

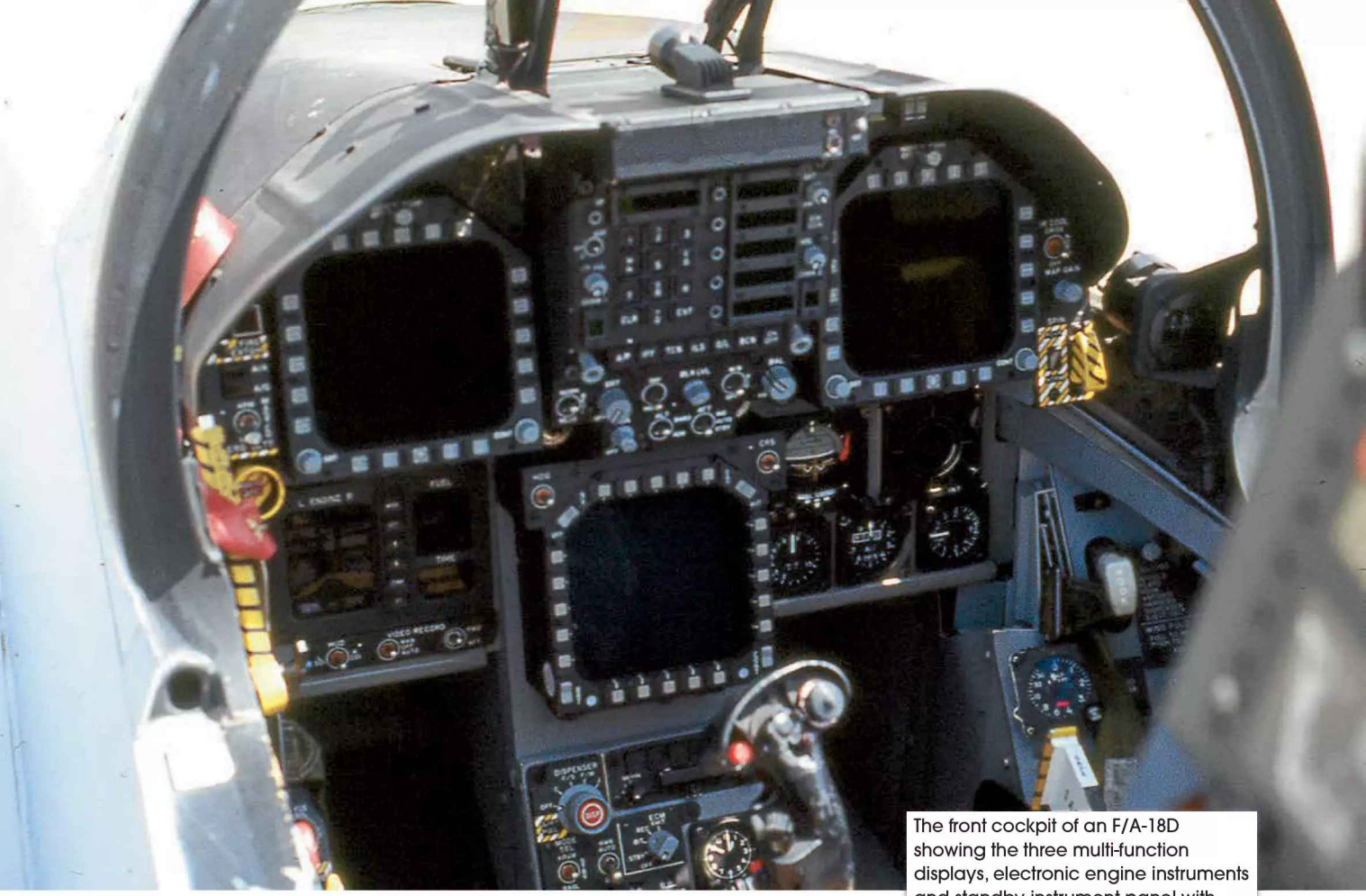
MALAYSIA

The Tentera Udara DiRaja Malaysia, the Royal Malaysian Air Force, underwent a series of modernisation programmes in the 1990s, including the acquisition of the BAE Systems Hawk and the Mikoyan Gurevich MiG-29N and UB in the air defence fighter and two-seat trainer roles.

This left the service with a gap in the all-weather interdictor and maritime strike role, which was filled in 1997 with the arrival of the first of eight F/A-18D Hornets to serve as two-seat strike aircraft. These aircraft underwent an upgrade in 2011 with the addition of a new GPS navigation system, improved cockpit displays and the JHMCS. On March 5, 2013, three Hornets and five Hawks took part in an attack on terrorist forces occupying a section of Northern Borneo which was followed by a ground operation by the Malaysian Army and Police forces.

One of Malaysia's F/A-18Ds was wrecked on August 21, 2025, due to a bird strike during take-off. Both crew ejected with the aircraft about 10m off the ground and the airframe's current status is unknown. Most likely, Malaysia now only has seven F/A-18Ds.

■ Words: *Tim Callaway*



The front cockpit of an F/A-18D showing the three multi-function displays, electronic engine instruments and standby instrument panel with the communications control panel mounted centrally below the head up display (HUD). **USMC**

The F/A-18 in detail

Close up with the strike fighter

Close examination of the Hornet reveals many fascinating details and shows the development of the aircraft over time. Some of the modifications were to solve problems encountered in service, some were to improve performance, but all of them add to the incredible aerodynamic form that is the F/A-18.

This section is a photographic montage intended to reveal and explain some of the features of the F/A-18's design. The photographs are from a number of sources, but particular mention must be made of Keith Draycott, who captured a number of F/A-18s 'up close and personal' in San Diego.

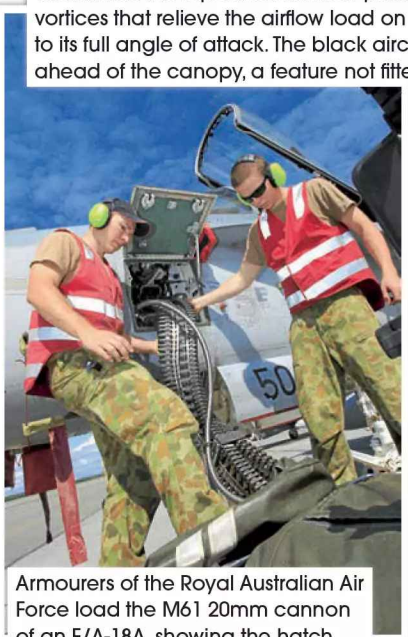
■ Words: *Tim Callaway*

The port side of the cockpit of an F/A-18C of the US Navy's VFC-12 shows canopy framing, HUD, ejection seat top and stencil and warning marking details. **Keith Draycott**

Looking down at the cockpit of an F/A-18A of the Royal Australian Air Force. Note the five vortex generators, HUD detail and canopy latches along the cockpit edge. **RAAF**

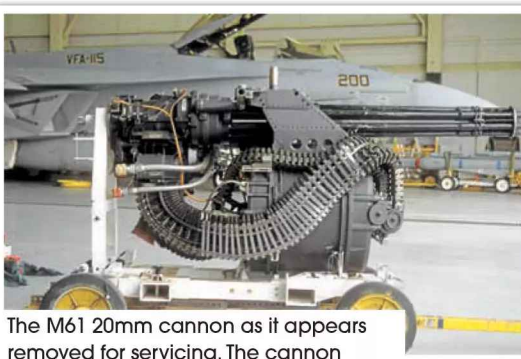
Two very differently marked F/A-18Cs of the US Navy's VFC-12 show the cannon muzzle port and nose mounted antennae clearly. On top of the leading-edge root extensions are the simple flat plates added to the Hornet after cracking problems were experienced with the fins on early aircraft. The black painted aircraft has the squadron number painted on the plate. These plates generate vortices that relieve the airflow load on the fins and allow the aircraft to be flown to its full angle of attack. The black aircraft has the five vortex generators added ahead of the canopy, a feature not fitted to all F/A-18s. **Keith Draycott**

The rear cockpit of an F/A-18D, the same aircraft as far left, showing the revised arrangement of the instrumentation and lack of a HUD. **USMC**

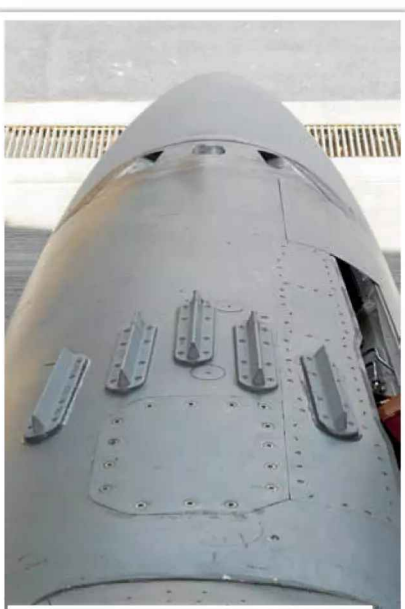


Armourers of the Royal Australian Air Force load the M61 20mm cannon of an F/A-18A, showing the hatch and cannon bay. **RAAF**

The cockpit area of an F/A-18A+ of the US Marine Corps'VFA-122 shows the ancillary cooling ducts for the radar and avionics just forward of the nosewheel door, as well as the fine aerodynamic edge of the leading-edge root extensions. **Keith Draycott**



The M61 20mm cannon as it appears removed for servicing. The cannon can be dismounted from the F/A-18 and replaced with various mission packages, including the ATARS reconnaissance pallet. **Luigino Caliaro**



The nose of a Royal Australian Air Force F/A-18A shows the five vortex generators, the cannon muzzle opening and the air-to-air refuelling probe recess. Note the forward door for the probe has closed. **RAAF**

A Royal Australian Air Force F/A-18A approaches a tanker with its inflight refuelling probe extended. **RAAF**

The nose of a CF-18A of the Royal Canadian Air Force reveals a wealth of detail, including the wingtip mounted 'exercise' sensor pack, inner pylon structure, under nose 'fake' canopy and a feature unique to RCAF aircraft, the nose mounted large spotlight for identifying aircraft intercepted at night. **Keith Draycott**

Looking down the sculpted interior of the engine air intake of a Royal Australian Air Force F/A-18A. **RAAF**

A close-up from the rear and above of the engine nozzles and arrestor hook of Royal Australian Air Force F/A-18A. **RAAF**

A fine front view of a NASA F/A-18B, showing the positioning of the undercarriage when the aircraft is on the ground. **Keith Draycott**

A close up of the fins and rear fuselage of an F/A-18A+ of the US Marine Corps…

…and the fins and rear fuselage of an F/A-18C of the US Navy. Note the different arrangement of antennae and sensors at the top of the fins – a major recognition point between the two variants of the Hornet. **Both Keith Draycott**

A front view of the starboard main undercarriage leg of a Royal Australian Air Force F/A-18A.The weight of the structure is more than made up for by the longevity the great strength gives the aircraft in service. **RAAF**

A US Navy F/A-18 is hooked up to the catapult and ready to launch as the deck crew make their last-second checks. Note the position of the tailplane and flaps for launch. **US Navy**

The nosewheel leg of a US Navy F/A-18 engaging with the catapult shuttle on board a carrier. The forces on the nosewheel leg on launch are tremendous; the entire weight of the aircraft is applied as the aircraft is accelerated. **US Navy**

A close up of the wingtip launch rail and position lights of a US Navy F/A-18A also shows the leading-edge slats, trailing edge flaps and their actuators in the drooped position. **Keith Draycott**

The nosewheel leg of an F/A-18A+ of the US Marine Corps with the catapult attachment arm in the raised position. The Australian Hornets were originally delivered without this arm, as they would not operate from carriers. A dummy version was added after it was discovered the arm helped prevent nosewheel shimmy. **Keith Draycott**

The forward fuselage of an F/A-18A+ of VFA-122 of the US Marine Corps, showing the intake spitter plates with their four rows of perforations, the leading-edge slot in the drooped position, the vortex generator plate on top of the leading-edge root extension and the centre line pylon. **Keith Draycott**

The main undercarriage of an F/A-18A+ of the US Marine Corps shows what a tough assembly this is, necessary to take the shock loads of carrier landings. The strength of the Hornet's undercarriage and airframe means it can bring unused weapons back to the carrier, not a common feature of naval aircraft. **Keith Draycott**

Laser guided bombs are waiting to be loaded aboard an F/A-18C. **US Navy**

Looking under the leading-edge root extension of a NASA F/A-18B showing the small slot at the rear of the extension and the arrangement of the ducts inside the intake spitter plates. **Keith Draycott**

The ubiquitous AIM-9 Sidewinder is most often carried on the wing tip rails of the F/A-18 for self-defence in the attack role or short-range engagements in the air-to-air role. **US Navy**

A US Navy F/A-18A+ of VFA-87 just before landing on the USS George H. W. Bush (CVN 77). Note how much further the main and nosewheel legs extend without the weight of the aircraft on them, and the position of the flaps, slats and arrestor hook. **Luigino Caliaro**

NASA's 846, resplendent among the aircraft participating in the 100th anniversary celebrations of Naval Aviation at San Diego in 2011. **Keith Draycott**

Chasing X-planes

NASA and experimental F/A-18s

Since the 1960s the National Aeronautics and Space Administration has operated a host of experimental aircraft and used fast jets to observe them in flight. When the agency's F-104N Starfighters needed replacing, it turned to the US Navy for a suitable replacement. The resulting small fleet of early F/A-18s has also been used for a host of airborne experiments such as the X-53 and HARV.

NASA's enduring relationship with the F/A-18 got off to an inauspicious start in October 1984 when the type's fifth pre-production full scale development aircraft, BuNo. 160780, arrived at the Dryden Flight Research Center at Edwards Air Force Base, California.

It was in bits on the back of an articulated lorry. Moreover, not only was it in pieces, 400 of those pieces were missing, having been stripped off it to patch up other F/A-18s in service with the US Navy. The aircraft had been effectively cannibalised as a source of spares. It took months for Dryden's mechanics to find all the necessary parts, cut out all the existing wiring then reassemble the aircraft from the ground up. When they'd finished the job they painted the slogan 'Silk Purse' on the side of the fuselage to indicate what they had made from the 'sow's ear' they'd been presented with.

BuNo. 160780 was given the civilian registration N840NA in September 1985. It initially served as a chase plane, joined the following month by the fourth production F/A-18A which became N841NA. This pair did not last long however, since 18 months later in April 1987 N840NA was enrolled in the agency's High Alpha Research Vehicle (HARV) programme.

THE HARV

The original meaning of HARV gave a better clue as to its purpose – High Angle-of-Attack Research Vehicle. Phase one of the programme, lasting until the end of 1989, involved N840NA flying at angles of attack as high as 55 degrees while fitted with an array of special instruments to measure the effects.

The unmodified but carefully monitored aircraft made its first HARV flight on April 2, 1987, with NASA research pilot Einar Enevoldson at the controls to check basic functions. He flew a further three HARV missions before two further NASA pilots, Bill Dana and Ed Schneider, took over and relatively minor modifications were made to the aircraft.

Video footage of tracer smoke flowing over different parts of the aircraft was shot to provide visual data on airflow during high angles of attack, the smoke itself being released through small ports forward of

Smoke generators and yarn tufts are used for flow visualisation studies on N840NA flown during the High Alpha Research Vehicle (HARV) project. **NASA**

The final flight for the HARV programme took place on May 29, 1996. F/A-18A N840NA is pictured during the flight, with NASA pilot Ed Schneider at the controls. Note the thrust vectoring hardware fitted to the aircraft's engine exhaust nozzles. **NASA**

the leading-edge extensions near the nose. Still images were also taken and these were used to examine the movements of short tufts of yarn taped to the aircraft as well as the progress of specially dyed antifreeze released on to the aircraft's surfaces from hundreds of tiny vents around its nose.

The film and photos were then used to compare the performance of the aircraft in flight to predictions made using computer and wind tunnel analysis. Extra data was generated during these test flights by pressure sensors fitted in a 360-degree arc around the Hornet's nose and at several other locations on the airframe.

The researchers focused most of their attention on strong vortices that formed around the wing leading edge extensions at high angles of attack and how they induced tail buffeting.

During the second phase of the HARV programme, N840NA was used to examine the manoeuvrability and control benefits of using vectored thrust at high angles of attack.

This involved major airframe modifications including a multi-axis thrust-vectoring control system with three paddle-like vanes fitted around each of the aircraft's engine exhausts and a new flight control system. The vanes, made of a nickel alloy containing heat resistant chromium and iron, enabled the pilot to apply both pitch and yaw forces to the exhaust flow without using any special controls once the system was switched on in flight. In addition, the engines had the divergent portion of their exhaust nozzles removed to shorten the distance the vanes had to be moved by about 2ft. All of this left the engines' performance largely unaffected but made supersonic flight impossible.

The thrust-vectoring gear added 2000lb to the total weight of the aircraft and a further 1500lb was added on top of that thanks to the inclusion of a spin parachute for safety, an emergency power system and ballast. Finally, an additional 419lb of wiring and other equipment not directly related to the thrust vectoring control system was added.

Second phase research flights using the new thrust vectoring equipment began in July 1991 and it was found that manoeuvrability was significantly enhanced at moderate angles of attack. There was also some improvement, though not so great, at angles of attack up to around 70 degrees. Bill Dana and Ed Schneider completed this round of tests in February 1992, having demonstrated stable flight at a 70-degree angle of attack and controlled rolling at a 65-degree angle of attack.

Unmodified, stable flight was barely possible in the Hornet at a 55-degree angle and controlled rolling was impossible above 35 degrees. The HARV programme continued from January 1993 to January 1994 with the addition of a sophisticated engine inlet pressure measuring system to more closely examine the effects of thrust vectoring and extreme angles of attack on engine airflow.

Ed Schneider and another pilot, Jim Smolka, carried out the next set of test flights between January and June 1994 – sometimes being joined for short periods by serving US Navy pilots.

Phase three was begun in March 1995 with the aim of evaluating moveable 4ft long by 6in wide strakes on both sides of the aircraft's nose. These were intended to provide controlled yaw at angles where conventional rudders became ineffective.

At long angles of attack, they folded flush against the sides of the aircraft but were extended as the angle of attack increased so as to interact with the strong vortices generated along the nose and provide a new degree of control. Test flights with N840NA were resumed in July 1995 and the new strakes allowed pilots to use three different flight modes.

The first used thrust vectoring alone, the second used thrust vectoring for pitch control and both vectoring and strakes for lateral control, and the third used thrust vectoring for pitch and just strakes for lateral movement.

The strakes project, and the HARV programme as a whole, came to an end

Heavily modified F/A-18A N840NA carries out airflow studies on a flight from the Dryden Flight Research Center. Using oil, researchers were able to track the airflow across the wing at different speeds and angles of attack. **NASA**

NASA'S 15 HORNETS

Type	Bureau number	Civilian registration	Date registered	Notes
F/A-18A	160780	N840NA	September 1985	Fifth full scale development (FSD) pre-production aircraft. Converted to High Alpha Research Vehicle (HARV). Now preserved at the Virginia Air & Space Center, Hampton, VA
F/A-18A	161216	N841NA	October 1985	Fourth production aircraft. Later returned to USN
F/A-18A	161214	N842NA	August 1987	Second production aircraft. On static display outside Municipal Baseball Stadium, Lancaster, CA
F/A-18A	161519	N843NA	October 1987	Ex Blue Angels, later returned to USN
F/A-18A	161213	N844NA	1987	First production F/A-18A. Crashed three miles north of Boron, CA, on October 7, 1988.
F/A-18B	160781	N845NA	July 1986	First pre-production TF/A-18A, later redesignated F/A-18B. NASA Systems Research Aircraft (SRA). Later returned to USN
F/A-18B	161355	N846NA	1987	Ex Blue Angels, now operational mission support aircraft (reg expires Oct 31, 2027)
F/A-18A	161520	N847NA	September 1989	Ex Blue Angels, operational mission support aircraft. Used as tanker aircraft in AAR experiments (reg expired Mar 31, 2012)
F/A-18A	161949	N848NA	December 1989	Sold to Spanish Air Force as C.15-81. Remains in active service
F/A-18A	161703	N850NA	N/A	48th Hornet built. Operational mission support aircraft (reg expires Oct 31, 2027)
F/A-18A	161705	N851NA	N/A	50th Hornet built. Mission support aircraft (reg expired Mar 31, 2012)
F/A-18B	161217	N852NA	N/A	Fifth production aircraft. Operational mission support aircraft (reg expires Feb 29, 2028)
F/A-18A	161744	N853NA	March 1999	Full scale Advanced Systems Testbed (FAST) aircraft. Used for AAW tests as the X-53 (reg expires Oct 31, 2027)
F/A-18A	161251	Not applicable	N/A	Used as non-flying systems test airframe
F/A-18D	164040	N862NA	July 2023	Chase plane for X-59 supersonic research aircraft

in September 1996 after a total of 385 flights. These had involved not only Enevoldson, Dana, Schneider and Smolka, but also guest pilots from the US Navy and Marine Corps, the Canadian Air Force, the RAF, McDonnell Douglas, Calspan plus additional NASA pilots based at both Dryden and the agency's Langley facility.

CHASE PLANES AND OTHER PROJECTS

While the HARV programme was being established, in January 1987, one of NASA's two surviving purpose-built Lockheed F-104N Starfighters, N812NA, was retired after 4442 flights since its introduction in September 1963. This left a gap in Dryden's roster and from late 1986 to late 1987 five more F/A-18s were drafted in to fill it.

The first of these, F/A-18A BuNo. 161214/N842NA, had already been involved in experimental work as part of the F/A-18R programme – the earliest attempt to produce a reconnaissance version of the F/A-18. During trials which began on August 15, 1984, BuNo. 161214 had been fitted with a sensor pack on a removable tray in place

Two NASA F/A-18s flown by research pilots Jim Smolka and Nils Larson cruise over the Texas landscape after a Stratospheric Observatory For Infrared Astronomy (SOFIA) check flight on May 10, 2007. **NASA**

NASA's workhorse F/A-18Bs pictured on February 21, 2001, after taking part in Autonomous Flight Formation experiments. These were to examine whether higher air traffic capacity and greater fuel efficiency could be achieved by automating close formation flying. **NASA**

The cockpit of the NASA SRA aircraft, an F/A-18B, fitted with the Southwest Research Institute's SWUIS-A digital imaging system on April 2, 2002. This was designed to look for tiny asteroids in space. **NASA**

of the 20mm M61 cannon in its nose. This included low-altitude cameras, low to medium altitude panoramic cameras and an infrared linescan camera for night work.

The programme was eventually shelved however and the aircraft was delivered to NASA.

This wasn't the last attempt to create a recon version of the F/A-18 however. Two years later, work began on the RF-18D. These were to carry an all-weather recce pod on the centreline station containing a UPD-4 SLAR high resolution synthetic aperture side-looking radar to supplement the F/A-18's nose-mounted optical and infrared sensors.

Images from this package were to be transmitted in real-time via an onboard datalink but could also be displayed in the rear cockpit. There was also apparently 'growth potential' within the pod for the installation of an electro-optical camera if required. At one stage it was planned that 83 RF-18Ds would replace the US Marine Corps' RF-4B Phantoms from 1990. In fact, the RF-18D's complete system and datalink had been successfully tested on an RF-4B before the project was cancelled in 1988. Plans to create a true reconnaissance version of the F/A-18 were finally realised in the mid-1990s with the creation of the F/A-18D (RC) – a batch of 60 F/A-18Ds built with a modified nose to take the ATARS sensor package in place of an M61 cannon.

Another two of NASA's five 1986-87 aircraft were former Blue Angels machines – N843NA and N846NA – an F/A-18A and F/A-18B respectively. The fourth, N844NA, was the first production F/A-18A and the fifth, N845NA, was the first pre-production prototype two-seat TF/A-18A, later redesignated F/A-18B.

The following year, the Dryden Flight Research Center was conducting flight tests with a range of exotically modified US military aircraft and experimental prototypes. The F/A-18s flew as chase aircraft to the X-29 advanced technology demonstrator, which had swept-forward wings, an F-14A fitted with laminar flow 'gloves' on its wings and an F-15A designed to detect and 'repair' damage to its own flight surfaces.

Disaster struck on October 7, 1988, when N844NA crashed three miles north of Boron, California, after its controls malfunctioned.

The aircraft was destroyed but the pilot Stephen 'Steve' D. Ishmael ejected and survived, albeit with a broken jawbone.

Two more Hornets arrived at Dryden in 1989, N847NA, another former Blue Angels aircraft, and N848NA, then another

Another unusual experiment for NASA's F/A-18s. N852NA has a Mars Science Lab test unit attached to its left wing – the landing radar for the next Mars rover. The outer casing is a Quick Test Experimental Pod (QTEP) designed to allow scientific equipment to be easily accessed and swapped if necessary. **NASA**

NASA's flexible-wing F/A-18A, redesignated as the X-53 due to the many changes to the airframe, manoeuvres through a test point during the second phase of the Active Aeroelastic Wing flight research project in December 2004. **NASA**

The Active Aeroelastic Wing F/A-18A shows off its form in a 360-degree aileron roll during a research flight. **NASA**

The upper wing surfaces of the Active Aeroelastic Wing F/A-18A test aircraft, N853NA, are covered with accelerometers and other sensors during ground vibration tests. An electro-mechanical shaker device, the blue cylinder to the lower right, generates vibrations into the airframe during the tests in August 2002. **NASA**

four were delivered during the 1990s – N850NA, N851NA, N852NA and N853NA. A final F/A-18A, BuNo. 161251, was turned over to NASA but was never registered for flight, being used instead as a static system testbed.

While experiments continued on N840NA – the HARV – a second NASA F/A-18 underwent significant modification. The first two-seat Hornet, N845NA, was fitted with what in 1993 qualified as the most advanced aircraft systems in the world to become the Systems Research Aircraft (SRA).

It carried out more than 20 experiments on technology including fibre optic sensor systems, the Real-Time Flush Air Data Sensing System which used pressure taps to measure altitude and wind speed/direction, laser-based systems, 'smart' skin antennae, reduced cockpit visibility systems and electronically controlled control surface actuators.

Along with N846NA, the SRA was used in Autonomous Formation Flight (AFF) experiments in 2001. These aimed to produce fuel savings and allow higher air traffic capacity by having one aircraft control another while flying in close formation. Close formation took advantage of the vortices generated by the lead aircraft, which, when flown in the optimum position, reduced the drag of the second aircraft and allowed it to burn less fuel. The SRA flew 200ft behind, 50ft to the side of and above N846NA and remotely controlled its lateral and vertical movements to match its own.

The following year, the SRA was used for 'airborne astronomy'. This involved the installation of the Southwest Research Institute's SWUS-A digital imaging system complete with camera for a series of flights to search for tiny asteroids thought to be circling between the orbit of Mercury and the sun.

Another experiment, in 2003, involved automated aerial refuelling. This evaluated the capability of the F/A-18A – specifically N847NA – as an in-flight refuelling tanker. The idea was to provide an analytical model for developing unmanned refuelling drones.

X-53 – 'FRANKENSTEIN'S HORNET'

While N845NA underwent substantial modifications to become the SRA, one of the 1990s NASA Hornets was so radically altered it officially joined the 'X-planes' series of experimental test vehicles as X-53.

N853NA was selected for the Active Aeroelastic Wing (AAW) flight research programme shortly after the US Navy handed it over to NASA in 1999. The programme had begun three years earlier at the Dryden Flight Research Center, with NASA working in conjunction with the US Air Force Research Laboratory and Boeing's Phantom Works – that company's department dealing with often top-secret cutting-edge military aviation projects.

The idea was to investigate the possibilities of a high-tech version of 'wing-warping'. This technique of bending a flexible wing structure to provide lateral control was developed by the Wright brothers at the dawn of the age of flight before ailerons were invented.

While the late 1990s saw much of the AAW programme's theoretical work being mapped out, work on altering N853NA

Structural loads testing on the Active Aeroelastic Wing F/A-18A, N853NA, at NASA's Flight Loads Laboratory in 2001. **NASA**

for the flight test phase was carried out between 1999 and 2001. This essentially involved taking the aircraft to bits and rebuilding it with an array of new sensors and test instruments – not to mention a suitably modified set of wings that had originally belonged to the HARV, N840NA.

Several of the existing wing skin panels along the wing box section just ahead of the trailing-edge flaps and ailerons were replaced with thinner and more flexible skin panels and structure. The wings also had more than 350 strain gauges installed on them to provide a detailed analysis of the structural effects of AAW movements.

Before it could be flown, the aircraft was subjected to a battery of experiments designed to test structural load, wing stiffness and levels of vibration. Its systems were checked and rechecked following the installation of new control software on its flight control computer.

In late 2002 the first phase of a two phase flight test programme began with 50 research flights to examine and measure the forces acting on the Hornet's twisting wing surfaces. These ended in April 2003 and a year of data analysis followed.

The second phase, to evaluate the handling and performance qualities of N853NA's flexible wings, started in late 2004 and was concluded in March 2005 after about 25 research missions at speeds ranging from Mach 0.85 to Mach 1.3 and altitudes from 5000ft to 25,000ft. When it became apparent that some test procedures required closer scrutiny, several additional flights were made.

The outcome of the tests was data that will be used to provide guidance for future aircraft designs that could make use of the Active Aeroelastic Wing. NASA believes that using AAW it will be possible to create such wing structures 10-20% lighter than those used on present day aircraft but still achieve the same levels of lift and control.

The technology, which could also help to reduce an aircraft's radar signature, is also thought to be potentially useful for a range of different future aircraft such as high-altitude long range unmanned drones, transport aircraft and commercial airliners.

The AAW project was funded through NASA's Aeronautics Research Mission Directorate and the USAF Research Laboratory but much of the practical engineering work was carried out by the Phantom Works, including the AAW wing modifications themselves, the installation of the wing instrumentation and some of the software.

Two further organisations, Lockheed Martin and BAE Systems, were also involved however. They developed the AAW research flight control computer and a third firm, Moog, developed the actuators for the outboard leading-edge flaps.

More recently, N853NA has taken on a new role as NASA's FAST – Full-scale Advanced Systems Testbed. It tests a range of fixtures, sensors and subsystems that are intended to be minimally intrusive to flight control systems, it can be used for experiments that require its structure and flight control systems to be extensively modified and it can even "validate new vehicle configurations", according to NASA.

SHAPE ADAPTIVE WINGS

When not directly involved in tests and experiments themselves, NASA's F/A-18 two-seaters are used for photo or video chase missions, while the fleet as a whole is used by Armstrong Flight Research Center pilots in Edwards, California, for routine flight training and proficiency exercises.

In 2018, a 300lb wing section was removed from one of Armstrong's F/A-18s so it could be used to test a newly developed mechanism for folding aircraft wings in flight. The Shape Adaptive Wings (SAW) technology involved the use of shape memory alloys – components that change shape when electrically heated, without the use of heavy hydraulic systems.

During the course of the project, an actuator made from nickel-titanium-hafnium was able to fold the 300lb F/A-18 wing segment through 90 degrees. According to NASA: "The implications of this technology include reduced aircraft weight, improved fuel efficiency, and enhanced carrier deck storage for naval aviation. Future applications may extend to variable-sweep wings, optimising aircraft aerodynamics across diverse mission profiles."

This was a static lab test, however, rather than any sort of real-world application, and it is not known which aircraft the wing section came from.

WHERE ARE THEY NOW

Test and experiments continued throughout the 2000s, but eventually the HARV was retired to a museum and a number of NASA's other F/A-18s were returned to the US Navy. The former F/A-18R test aircraft, flown by NASA as N842NA, ended up plinthed outside the Municipal Baseball Stadium in Lancaster, California, and one of the later NASA Hornets, N848NA, was sold to the Spanish Air Force as C.15-81, and was still in service as of April 2025.

Today, five of NASA's F/A-18s remain in service – the X-53 test aircraft N853NA, a pair of two-seater F/A-18Bs (N846NA and N852NA), a single F/A-18A (N850NA) and the 'new' two-seater F/A-18D, N862NA.

■ Words: *Dan Sharp*

The X-53 Full-scale Advanced Systems Testbed was also used in the Intelligent Control for Performance (ICP) flight research project. It is seen here with NASA F/A-18B N846NA in support on October 16, 2012, on the last flight of the ICP programme. The flights evaluated a peak-seeking algorithm installed in the aircraft's flight control computer that allowed the system to precisely adjust flight control surface deflections to reduce aerodynamic drag, and thus improve fuel consumption during cruise flight. **NASA**

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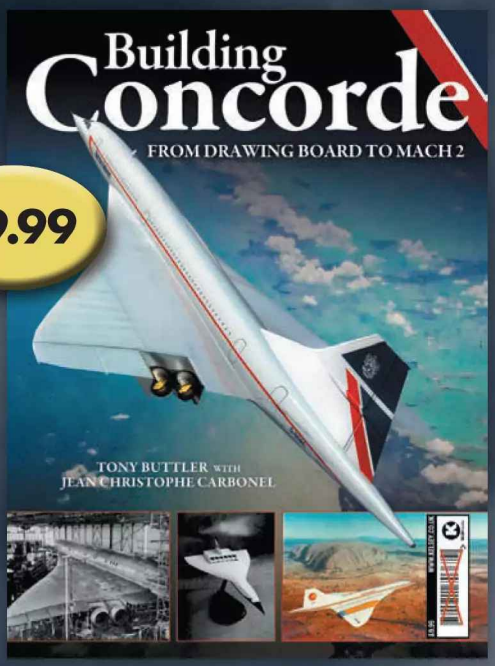

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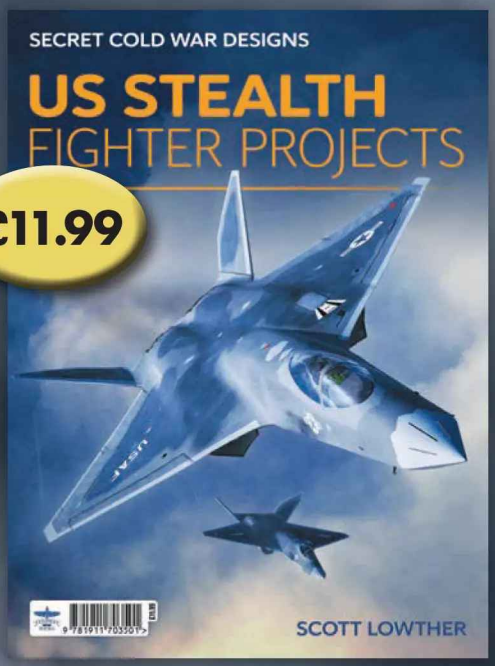

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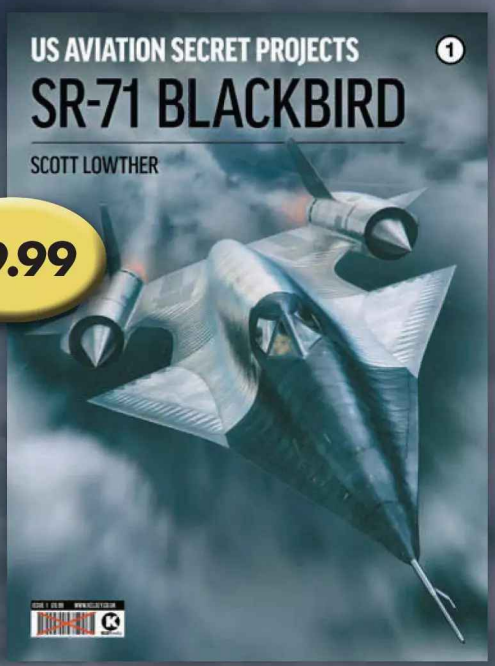

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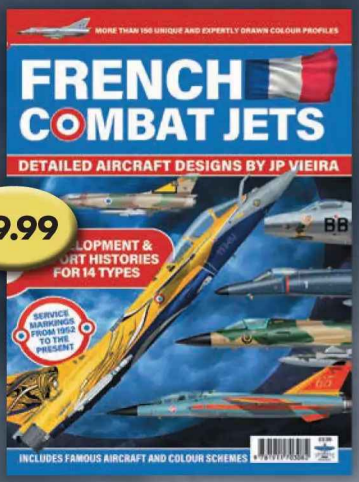
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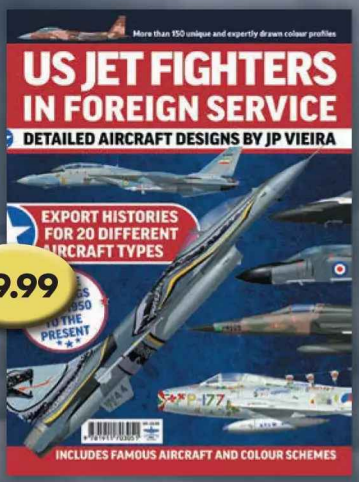
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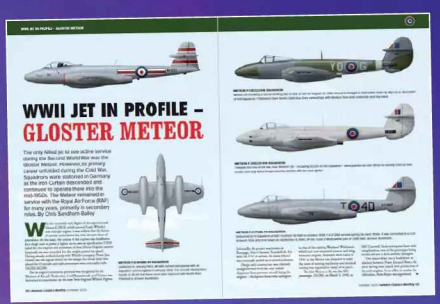

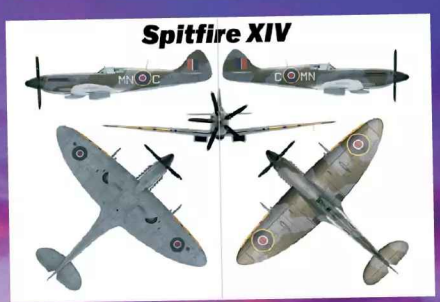

Aviation Classics Monthly magazine

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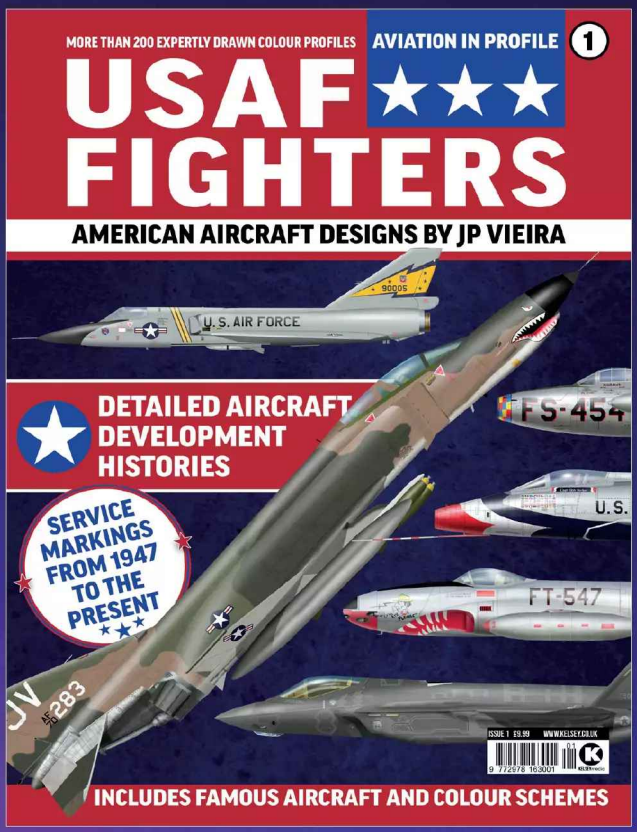
Aviation in Profile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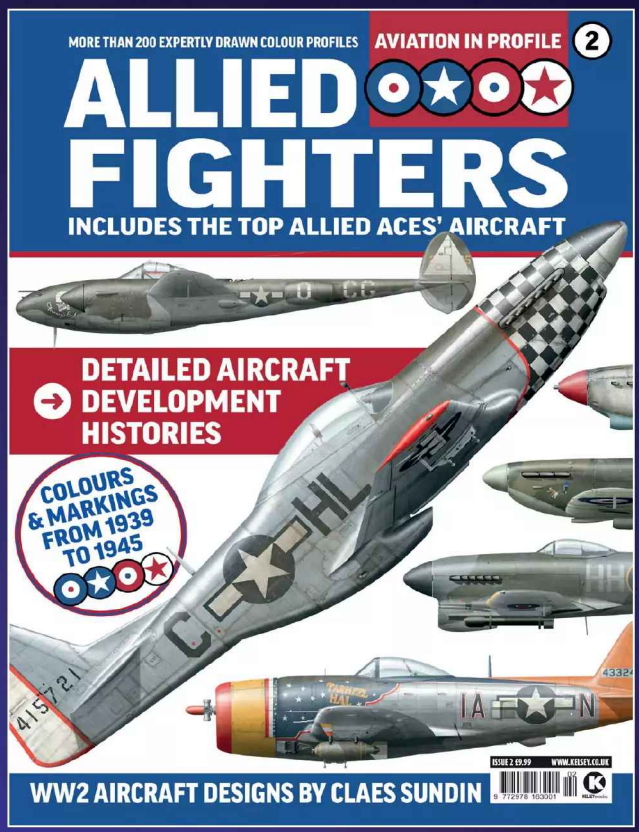
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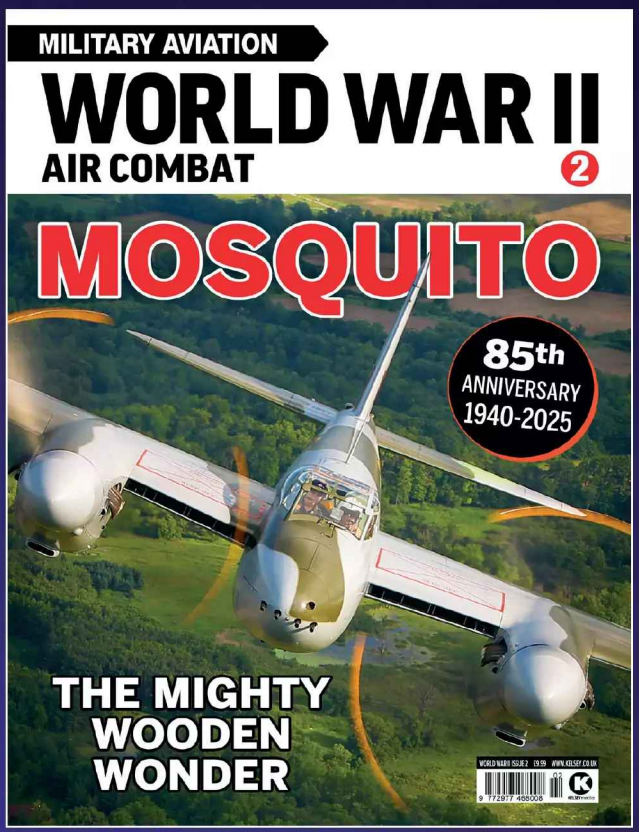
The colours and markings worn by aircraft have been a source of fascination for aviation enthusiasts and modellers since the dawn of aviation itself. Camouflage patterns, national insignia, unit markings, nose art and even streaks of oil and dirt can reveal everything about an aircraft – from the air force flying it to its operational role, theatre of service and even the identity of its pilot. Every issue of Aviation in Profile, published quarterly, features more than 150 highly detailed and expertly-drawn profile artworks depicting famous and noteworthy aircraft from a particular air force, conflict, time period or nationality. Whether it be jet fighters of the USAF, piston engine fighters of the RAF, bombers of the Luftwaffe, French combat aircraft or aerobatic display teams, Aviation in Profile offers a wealth of incredible artworks to marvel at. Alongside the art can be found full aircraft development histories, as well as detailed captions explaining the background of each airframe depicted – where and when they served, the unit or company to which they belonged, the pilot or crew who flew them and more. For aircraft modellers, the collectable Aviation in Profile series will prove a valuable source of inspiration with each issue offering a wide variety of liveries and colour schemes to consider. For aviation history enthusiasts, the series provides a fascinating look at how each aircraft type was developed from drawing board to the end of its service career.

World War II Air Combat



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The complete story of famous and successful aircraft of the RAF, USAAF and Luftwaffe, such as the revolutionary de Havilland Mosquito, the iconic North American P-51 Mustang, the mighty Boeing B-17 Flying Fortress and the outstanding Focke-Wulf Fw 190, is told from the drawing board to the front line and beyond, with a look at surviving airframes and the museums that preserve them for future generations to come.

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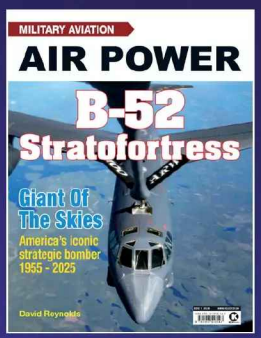
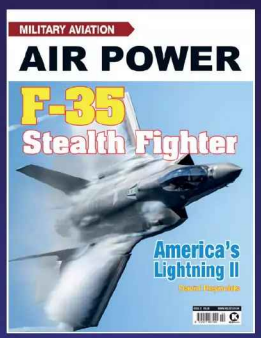
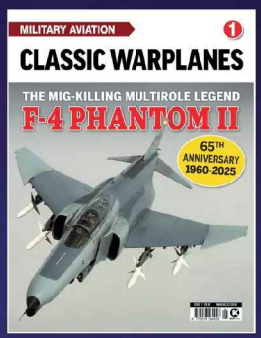
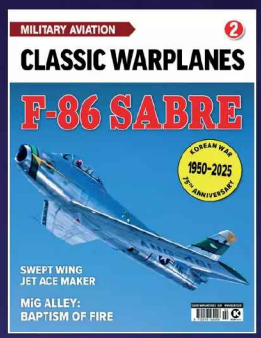
Air Power and Classic Warplanes









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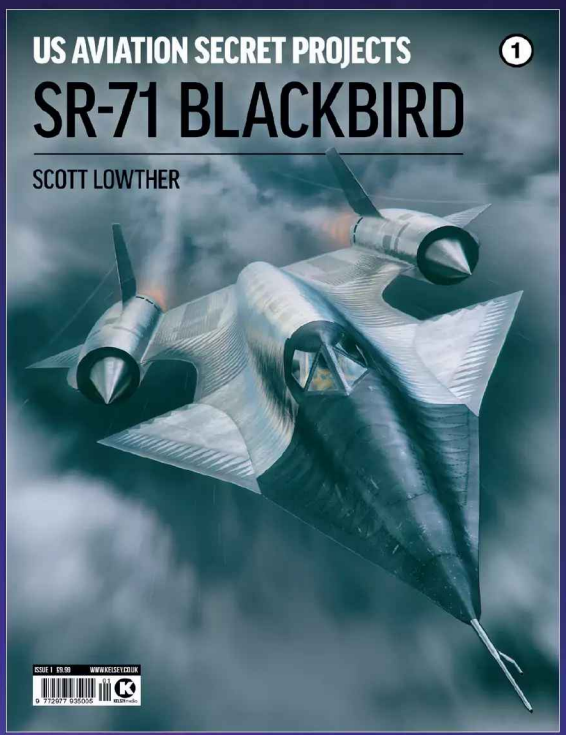
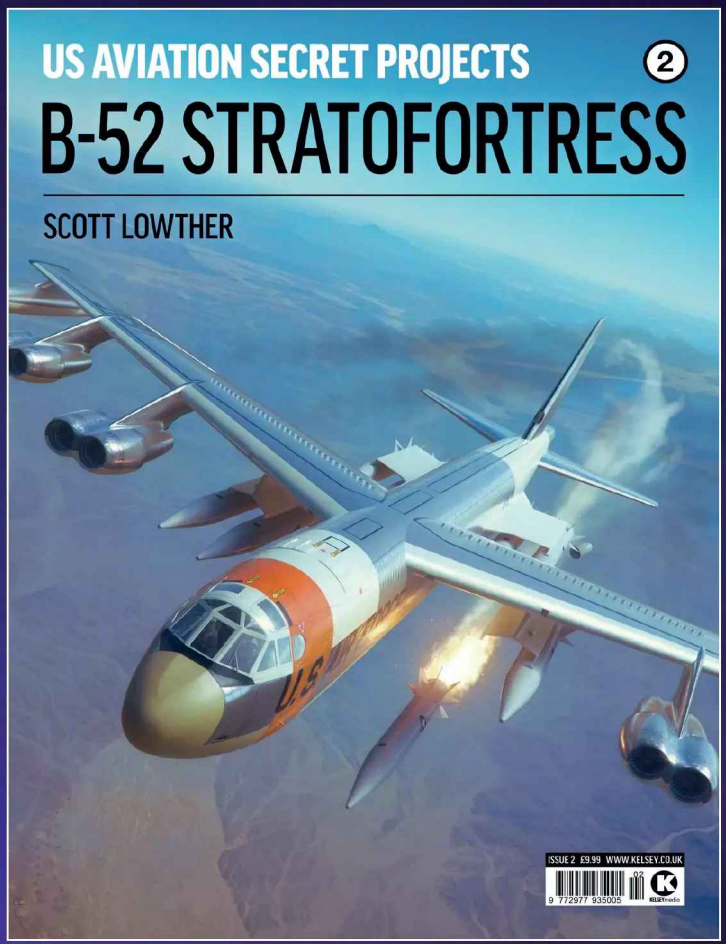
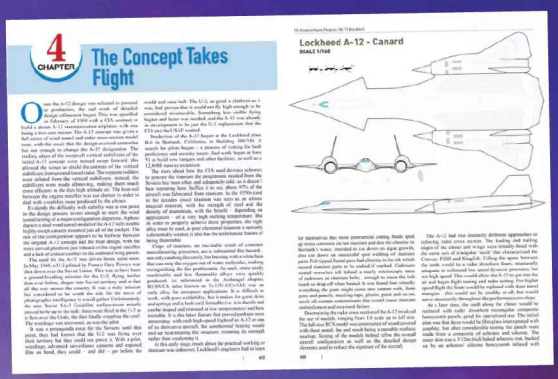
Classic Warplanes bookazine series

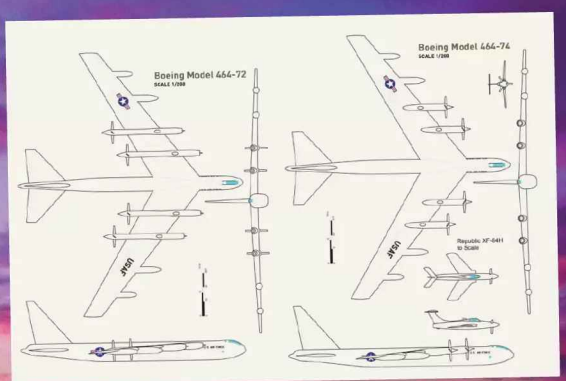
Devoted to the world's greatest flying machines, the Classic Warplanes series celebrates legendary aircraft from the beginning of the Cold War right up to the spectacular innovations of the present day. Every issue, published quarterly, tells the complete story of an aerospace legend such as the rugged multirole McDonnell Douglas F-4 Phantom II fighter, the magnificent Avro Vulcan bomber or the innovative cannon-armed scourge of MiG Alley – the North American F-86 Sabre. The origin of each type is fully explored, including the designers and engineers whose meticulous and painstaking work brought them to life. Prototypes and early testing, entry into service and operational careers are all examined and explained in authoritative detail. Period and modern photography, colour illustrations and graphics all help to tell the tale of these incredible aircraft and the people who designed, built, flew and maintained them. And what's more, lesser-known features and unusual missions are highlighted and discussed too, to give a fully rounded account of exactly what made these outstanding machines so special – ensuring their status as true classics. Compelling, informative and collectable, the Classic Warplanes series is a must-read for anyone who loves aircraft and aviation.

US Aviation Secret Projects









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Behind every world-famous American aircraft – from the cutting-edge Lockheed F-22 Raptor to the long-serving Boeing B-52 Stratofortress – there exists a secret history of aircraft designs that were planned but never built. For every Rockwell B-1 Lancer or General Dynamics F-16 Fighting Falcon that has entered production there have been dozens, perhaps even hundreds, of concepts; evolutionary steps which saw the final design gradually growing and taking shape on the designers' drawing boards. In the US Aviation Secret Projects series, American aerospace engineer and aircraft development specialist Scott Lowther looks in detail at the vast range of different variants and configurations proposed for some of the United States' most innovative and advanced aircraft. Each issue is fully illustrated throughout with scale diagrams showing the many different designs studied, with dimensions and technical information provided where known.

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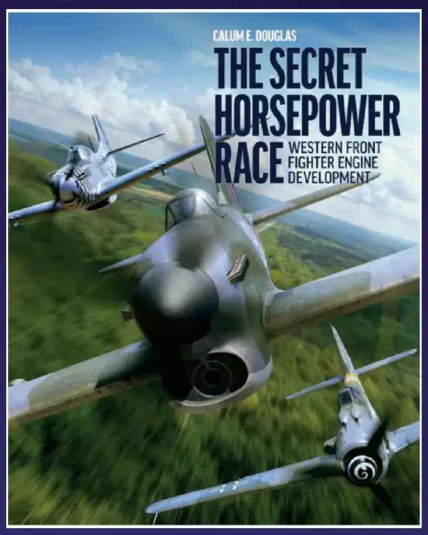

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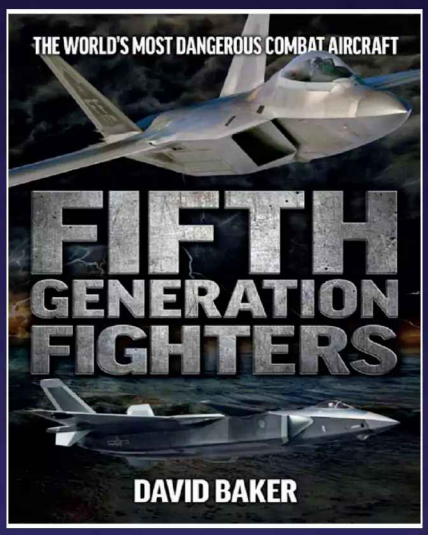

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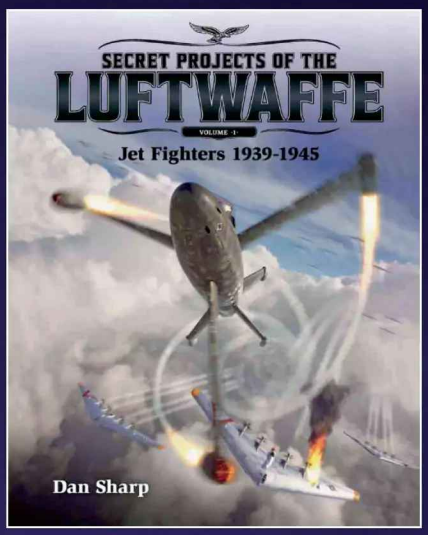

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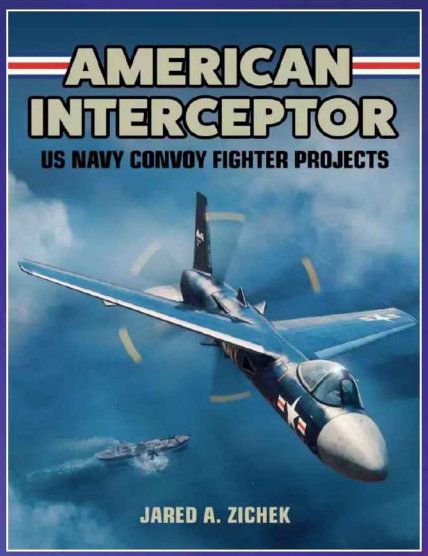

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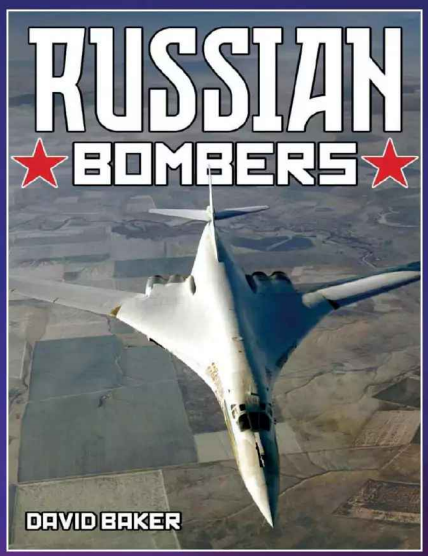

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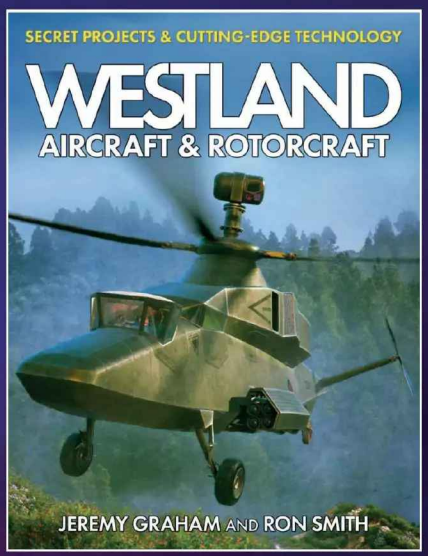

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